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ORIGINAL ARTICLES.

I.—Henry Clifton Sorby, and the Birth of Microscopical Petrology.

(WITH A PORTRAIT, PLATE VIII.)

JUST half a century ago, the Geological Society was engaged in passing through the press a very remarkable memoir—a memoir that was destined to revolutionize one of the branches of the science which the Society had been founded to promote. Yet on its appearance this memoir, "On the Microscopical Structure of Crystals," was met with ridicule on the part of some, with scepticism by others, and by a neglect that was almost universal. Nevertheless, its author, Mr. Sorby, lived to find Microscopical Petrography recognised all the world over as one of the most important branches of geological science, to see appearing year by year an enormous mass of literature devoted to this branch of science, and to be himself hailed by the geologists of all lands as the pioneer in this new and fruitful field of scientific research.

It is an interesting task to trace the movements of the master mind in the various stages of the evolution of this new scientific method; and this task has become a duty inasmuch as very misleading statements on the subject have obtained a somewhat wide currency. It is a fortunate circumstance that Sorby has himself left us a number of autobiographical reminiscences[1] which enable us to trace the gradual development of new methods and fruitful ideas, and at the same time to remove prevalent misconceptions on the subject.

The family of Sorby (or Sowerby) is one having many offshoots in Yorkshire, and the particular branch to which the geologist belonged is said to have been established in Sheffield ever since the time of Henry VIII. Sorby's father was a partner in a firm of edged-tool manufacturers and a colliery proprietor, who resided at Woodbourne, then an outlying country-house, but now enclosed in the busy district

[1] "Unencumbered Research: A Personal Experience," by H. C. Sorby: one of a volume of "Essays on the Endowment of Research," published in 1876 (pp. 149–175). "Fifty Years of Scientific Research": an address delivered before the Members of the Sheffield Literary and Philosophical Society, at Firth College, on Tuesday, February 2nd, 1897.

of Attercliffe. At this house Sorby, who, I believe, was an only child, was born on May 10th, 1826.

When about seven years of age the boy was sent to a dames' school at Harrogate, and here I may notice a curious coincidence not without interest to geologists. Young Sorby became the playfellow of another child residing in the same town, whose father was part-proprietor with the Sorbys of the Orgreave colliery a few miles away from Sheffield. The children parted in 1834, not to meet again for forty-four years, when Sorby had become President of the Geological Society, and the other lad, Mr. W. H. Hudleston, one of the leading workers in the geological world. The two playfellows both grew up to be Presidents of the Geological Society and recipients of the Wollaston Medal.[1]

After leaving Harrogate, Sorby went to the Collegiate School (now the Grammar School) of Sheffield, where he tells us that he received a prize entitled "Readings in Science," which had a large share in directing his mind into the channel of scientific research. A still more important influence was exercised, however, by the instructions of a mathematical tutor under whom he was placed on leaving school. This tutor, the Rev. Walter Mitchell, who is known as the author of a treatise on Crystallography published in Orr's "Circle of the Sciences," and some original papers on the same subject, had been a medical student, and was able to instruct Sorby both in Chemistry and Anatomy. At a very early age Sorby seems to have made up his mind to devote his life to scientific research, and to this end he tells us that, besides studying various branches of science, he laboured to make himself proficient in drawing and the representation of objects in colour. From the very first, Sorby appears to have set his face against any attempt to obtain academic distinction or the passing of examinations. To have a well-trained and untrammelled mind in a healthy body was always the one object of his ambition.

Sorby constantly maintained that the true atmosphere for a life of scientific research could only be obtained by leisure and mental quiet, and a complete absence of those pressing cares incident to a business or profession. His own circumstances were particularly fortunate ones, for he succeeded to a moderate but easy competence. In 1876 he writes: "Original research can be carried on in a satisfactory manner only when an investigator has abundance of time for work, and freedom from those cares that interfere with reflection. I am thankful to say that complete immunity from such routine employment" (a business or profession) "has been my own happy lot. My entire life has been spent either in scientific research or in preparation for it." ("Unencumbered Research," pp. 149–150.)

An additional advantage enjoyed by Sorby was that of being, like Darwin, free from the important, though often harassing, duties connected with scientific societies and similar organisations. The

[1] I am indebted to my friend Mr. Hudleston for information upon which the above statements are based, and he also tells me that the Orgreave property is in the district rendered famous in Scott's "Ivanhoe."

cause of this was not, as in Darwin's case, ill-health, but a perhaps over-scrupulous devotion to a widowed mother who begrudged the time that might have been lost by frequent visits to London. During his mother's life Sorby was accompanied by her on all his summer expeditions, and, indeed, he seldom, if ever, left Sheffield without her.

When only 20 years of age Sorby commenced his scientific publications by a paper on Agricultural Chemistry, which was read at the Chemical Society in December, 1846.[1] This paper was based on 132 determinations of sulphur and phosphorus, made by himself, in different crops. Very soon, however, his attention was directed to a subject which all through his life had a great fascination for him, namely, the mode of deposition of sedimentary deposits, and the conclusions that may be derived from their study. The gardens of the house at Woodbourne ran down to the River Don, and here he carried on various experiments on the flow of water and the deposition of sediment. He tells us, too, that one day, while walking out to Orgreave, he was caught in a shower of rain, and whilst sheltering in a quarry near Handsworth his attention was directed to the current-structures exhibited in the sandstone rocks. For these structures he proposed a new classification, and he also prepared a map of the Rother and Don to illustrate the changes in the courses of these rivers.[2] (See "Fifty Years of Scientific Research," p. 4.)

Sorby has told us in very explicit terms how his mind was first drawn to the study of rocks—by means of thin sections for examination under the microscope—at a date long anterior to the publication of the epoch-making paper we have alluded to at the commencement of this article. After stating that at a very early date he was attracted to the study of the shells in the Bridlington Crag, and that he employed the microscope in their study, he says that he had made the acquaintance of William Crawford Williamson, while they were both very young and were journeying together from Scarborough to York. Williamson was an adept in the preparation of sections of hard substances for microscopical study. His maternal grandfather and uncle (the Crawfords) were skilful lapidaries, and young Williamson in his youth learned the use of diamond- and emery-wheels and the general art of the lapidary. (See "Reminiscences of a Yorkshire Naturalist," 1896, pp. 5-6.) Sorby says that he was led to visit Williamson at Manchester some time between 1842 and 1849, and "found him making sections of fossil wood, teeth, scales, and bones. He showed me how to prepare them, and on my return home I made similar sections. It occurred to me, as early as 1849, that a great deal might be learned by applying a similar method to the study of the structure of rocks, and I show

[1] Chem. Soc., Mem. iii (1845-8), pp. 281-284; Phil. Mag., xxv (1847), pp. 330-334.

[2] Sorby's papers on these subjects will be found in Sheffield Lit. and Phil. Soc. Rep., 1847, Aug. 6, Dec. 3; 1848, March 3; 1850, p. 13. Proc. W. Yorks. Geol. Soc., iii (1851), pp. 220-224; (1852), pp. 232-240; ibid., vii (1854), pp. 372 et seq. Proc. Yorks. Phil. Soc., i (1856), pp. 372-378. Brit. Assoc. Rep. (1855), pt. 2, pp. 97-98; (1856), p. 77. Sheffield Lit. and Phil. Soc. Rep. (1858), p. 9. Brit. Assoc. Rep. (1858), pt. 2, p. 108. *Geologist*, vol. ii (1859), pp. 137-147, etc.

a slide prepared from what is probably the first transparent microscopic section of a rock ever prepared, and also exhibit another slide from the first drawing of the structure made in 1849."[1] He goes on to relate: "My first published paper in connection with the structure of rocks was in relation to an interesting deposit called the Calcareous Grit, below the Castle Rock at Scarborough. I wrote a paper, sent it to the Geological Society, and it was published by the Society in 1850. That paper was the first of its type, and it is interesting to refer to it because at that early date I had developed almost all the methods that are employed even up to the present day in studying the microscopic structure of rocks." ("Fifty Years of Scientific Research," p. 5.)

This early paper seems never to have attracted the attention it deserved. That Sorby's estimate of its importance is not by any means exaggerated will at once appear upon a perusal of it. Sorby separated the constituents of the rock both by mechanical and chemical methods; he determined the proportions of these constituents to one another, measuring their particles down to the $\frac{1}{2000}$ of an inch; he prepared sections of the rock, little more than $\frac{1}{1000}$ of an inch thick, finding it necessary to make some of these sections of large size; and not only did he employ very high powers of the microscope, but he used polarized light, both parallel and convergent, and showed their use in distinguishing between calcite, quartz, and chalcedony.

This little memoir, which was read before the Geological Society on November 6th, 1850, gave, in fact, a remarkable forecast of the methods and modes of reasoning which have brought microscopical petrography to its present position as a branch of geological research. The paper, as published in the Quarterly Journal of the Geological Society (vol. vii, pp. 1–6), was without illustrations, but a plate with some of Sorby's own drawings was published in the Proc. W. Yorks. Geol. Soc., iii (1851), pp. 197–206.

Sorby continued all through his life this work on the structure of limestones and other sedimentary rocks, being led especially to note the part played by calcite and aragonite, and the wonderful pseudomorphic changes going on in calcareous deposits. To this subject he devoted his two addresses to the Geological Society in 1879 and 1880, and his latest memoir, completed on his deathbed, was a further exposition of the problem.

But Sorby's studies were not by any means confined to the calcareous rocks. He informs us that Daniel Sharpe's writings directed him in 1851 to the study of slaty cleavage, and of his work in this direction he writes as follows:—"For some time I had been occupied with the study of the microscopical character of rocks possessing slaty cleavage, a problem which had previously attracted much attention, but was still involved in so much obscurity that several theories, all equally unsatisfactory, had been propounded. The more I studied the microscopical structure of these cleaved rocks, the more was I puzzled with the observed facts. One day when quietly walking in my garden and

[1] We understand that these early sections and drawings are to be preserved in the City Museum at Sheffield.

reflecting on things in general the simplest possible explanation of the whole flashed across my mind. I immediately went to my work-room, mixed some small pieces of coloured paper with wet pipeclay, and on compressing them in the manner that slate rocks are proved to have been compressed, I found that I obtained a very good representation of the characteristic structure on which their cleavage depends. From that moment forwards the whole theory of cleavage took a new shape in my mind, and after studying by experiment, with the microscope and in the field, those facts which this new hypothesis indicated as important, in a few years I had the satisfaction of finding that it was universally accepted as a satisfactory explanation of one of the great phenomena of geology." (Essay on "Unencumbered Research.")

When Sorby brought forward his theory of slaty cleavage it was met, as he informs us,[1] with great opposition on the part of those in authority, and in consequence of this opposition he withdrew the paper which he had sent to the Geological Society, and forwarded it to the Edinburgh Philosophical Journal.[2]

The study of the microscopical structure of slates naturally led to the examination, in the same way, of the schists, and after some years of work upon them Sorby published his papers on mica-schist, in which he enunciated his theory of stratification- and cleavage-foliation.[3] It is worthy of note that in these papers he shows that he was already alive to the great importance of studying the nature of the cavities contained in the crystals of rocks, and the substances which they contain. In his paper on mica-schist he proved that some cavities contain water, and in a paper published about the same time on the Magnesian Limestone[4] he indicated that the cavities contain aqueous solutions. It was at a later date (1869) that he proved carbon dioxide in a liquid state to be present in some of these cavities.

It will be seen from the above account that Sorby's work in microscopic petrography commenced in 1849, was carried on by him continuously down to 1856, and, therefore, that the statements which have been made that in the year 1856 he first learned how to cut sections from rocks from Alexander Bryson, who had in turn been taught by William Nicol,[5] have no foundation in fact.

Everyone will acknowledge the valuable work done by the ingenious William Nicol in preparing the sections of fossil wood for Witham's work on the subject. I am not aware, however, that Nicol anywhere claims to have invented the method. Alexander Bryson, indeed, in

[1] "Fifty Years of Scientific Research," pp. 5–6.

[2] Edinb. New Phil. Journ., lv (1853), pp. 137–150; Proc. W. Yorks. Geol. Soc., iii (1853), pp. 300, 311; Phil. Mag., xii (1856), pp. 127–129. In 1876 I induced Sorby to exhibit some of the artificial products and specimens on which he based his conclusions concerning slates and schists to the Loan Exhibition of Scientific Objects, and these are still to be seen in the Science division (Geological Section) of the Victoria and Albert Museum, South Kensington.

[3] Brit. Assoc. Rep. (1856), pt. 2, p. 78; Edinb. New Phil. Journ., 2nd s., iv, p. 370.

[4] Brit. Assoc. Rep. (1856), pt. 2, p. 77.

[5] "The Founders of Geology," 1st ed. (1847), pp. 276–280, and 2nd ed. (1905), pp. 162, etc. "The History of the Geological Society of London" (1907), pp. 170–172.

a paper written in 1856, states, "The method of preparing fossil woods and other inorganic substances for examination under the microscope had its origin in this city" (Edinburgh). "But as the claims of two or three eminent individuals (all deserving praise) are mingled in this improvement, I refrain from considering them."[1] As a matter of fact, Brewster employed thin sections of minerals before 1816, and many anatomists made transparent sections of bones and teeth at a very early period. Sorby, as we have seen, tells us that Williamson,[2] who had learnt the lapidary's art as a boy, and was a pupil of Sharpey in London, taught him, in 1849, how to make sections of hard substances, and that he himself perceived the importance of applying the method to the study of rocks. Bryson informs us that he showed his own and Nicol's collections of sections to Sorby in 1856; but after the latter had published his important paper in 1858 Bryson wrote to dispute his conclusions in a paper on the "Aqueous Origin of Granite."[3]

The manner in which Sorby was led from the study of limestones, slates, and schists to that of the igneous rocks has been well described by himself. After stating that the physical conditions under which certain kinds of rocks are formed at a great distance below the surface of the earth had constantly engaged his attention, he says: "Their microscopical structure had been most puzzling. The evidence of igneous fusion and of the presence of liquid water were about equally strong, and for some time it seemed difficult to adopt any theory which assumed either igneous or aqueous origin of such minerals and rocks. All at once the correct explanation flashed upon me. Both igneous and aqueous action must have occurred more or less simultaneously, and the facts which I published have, as I believe, had no small share in causing such a theory to be almost universally accepted by geologists." ("Unencumbered Research," pp. 158–159.)

Sorby's epoch-making memoir was read at the Geological Society on December 16th, 1857, under the title "On some Peculiarities in the Microscopical Structure of Crystals, applicable to the determination of the Aqueous and Igneous Origin of Minerals and Rocks."[4] His account of what took place on that occasion is very interesting. He says: "My late good friend Leonard Horner was the chairman, . . . after I had read this paper he said he had been a member of the Geological Society ever since its foundation, and during the whole of

[1] Edinb. New Phil. Journ., iii (1856), pp. 297–308.

[2] William Crawford Williamson had almost as versatile a genius as Sorby himself. At a very early age he originated, by his study of the Yorkshire cliff-sections, the zonal classification of strata by the aid of their fossils. At a subsequent date he led the way in this country to the study of the Foraminifera and the microscopical characters of their shells. All the later years of his life were devoted to the study of coal-balls, and to the important results of fossil botany that this study originated. Yorkshire may well be proud of having produced in a single generation two such men as Williamson and Sorby!

[3] Edinb. New Phil. Journ., xv (1862), pp. 52–55.

[4] The paper, which was published in November, 1858, and was illustrated with three plates of interesting drawings made by Sorby himself, appeared under the title "On the Microscopical Structure of Crystals, indicating the Origin of Minerals and Rocks": Quart. Journ. Geol. Soc., vol. xiv, pp. 453–500.

that time he did not remember any paper having been read which drew so largely on their credulity. But very fortunately I had taken some microscopes and objects with me and had shown them to my friend Professor Phillips, of York. He got up and said the chairman might speak as he had done, but he had nothing to do but look through the microscopes and see that such things existed, and they might depend on it, in a few years, the facts that Mr. Sorby had described would be universally acknowledged to be correct, which has turned out to be true." ("Fifty Years of Scientific Research," p. 9.)

In spite of John Phillips' characteristically generous intervention, Sorby's paper did not for a long time gain the attention which it deserved. Sorby says himself: "In those early days people laughed *at* me. They quoted Saussure, who had said that it was not a proper thing to examine mountains with microscopes, and ridiculed my action in every way. Most luckily I took no notice of them." ("Fifty Years of Scientific Research," p. 5.)

It was in Germany and on the part of Dr. Ferdinand Zirkel that Sorby's work was destined to find full and complete recognition. The story has been so well told by Fouqué, the account being endorsed by Zirkel himself, that we cannot do better than to quote it:

"En 1862 il [Sorby] avait entrepris avec sa mère un voyage d'agrément sur les bords du Rhin. Arrivé à Bonn, il fit connaissance d'un élève du corps des mines de Prusse, nommé Zirkel, par lequel il fut accompagné et dirigé dans quelques excursions. Ils visitèrent ensemble l'Eifel, le Siebengebirge, et les environs du lac de Laach. Chaque jour, chemin faisant, une conversation intéressante et animée s'engageait entre le touriste et son guide sur la nature des roches volcaniques, sur les minéraux qui les composent, et sur les merveilleux détails de structure que le microscope y révèle. Sorby exposait avec clarté et chaleur les magnifiques résultats de ses études. Le soir, après l'excursion de la journée, l'entretien se prolongeait encore. Enfin, de retour à Bonn, le maître improvisé mit sous les yeux de son jeune auditeur quelques préparations microscopiques qu'il avait apportées, et lui fit apprécier par lui-même la netteté et l'importance des faits qui avaient été l'objet de leurs longues causeries. Quelques jours plus tard, en quittant Zirkel, il laissait en lui un disciple enthousiaste, qui, désormais se consacrant entièrement aux études de géologie micrographique, allait bientôt dans cette voie marcher de découvertes en découvertes, grouper autour de lui un essaim de travailleurs, et devenir l'un des savans les plus célèbres de l'Allemagne."[1]

So much in earnest was Zirkel that he at once proceeded to the laboratory of the Reichsanstalt at Vienna, and as the result of his work during the winter prepared a memoir only second in importance to Sorby's own paper. This paper, containing descriptions of the microscopical characters of thirty-nine very typical rocks, was read before the Vienna Academy[2] on March 12th, 1863. With splendid

[1] *Revue des deux mondes*, July 15th, 1879, p. 409.

[2] "Mikroskopische Gesteinstudie": Sitzungsb. d. k. Akad. d. W. math. naturw. Cl., Bd. xlvii, Abth. 1 (1863), pp. 228–290.

energy Zirkel continued his labours in the new field of research, and published in succession a number of valuable papers in which minerals like leucite, nepheline, apatite, sphene, etc., were recognised as rock-constituents; and he found a worthy coadjutor as enthusiastic as himself, in his brother-in-law, Hermann Vogelsang, whose "Philosophie der Geologie und Mikroskopische Gesteinstudien," published in 1867, and illustrated by descriptions and beautiful drawings of rock-sections, did much towards making the new method of research widely known. Investigators like Heinrich Fischer, Tschermak, Doelter, Von Lasaulx, and many others took up the work, and numerous papers on the subject were published. In 1873 microscopical petrography may be said to have become established as a recognised department of geological science by the publication of two very important works. Zirkel, himself, gave to the world his "Mikroskopische Beschaffenheit der Mineralien und Gesteine," full of very detailed descriptions of the minute characters of minerals and rocks, while Heinrich Rosenbusch, in his "Mikroskopische Physiographie der petrographische wichtigen Mineralien," developed the optical principles on which mineral determinations must be made by the aid of the microscope. The publication in 1877 of Rosenbusch's "Mikroskopische Physiographie der massiger Gesteine," and in 1879 of Fouqué & Michel-Lévy's "Minéralogie micrographique des roches éruptives françaises," with its magnificent atlas of plates, followed by the numerous memoirs of these two authors, and by Lacroix, showed how abundant was the harvest which had sprung from the seed sown by Sorby in 1850.

It has often been remarked as strange that Sorby did not himself do more in cultivating the field of research which he had so happily discovered. It is true that he never lost his interest in the subject, as was shown by numerous papers on the structure of the sedimentary rocks, on new applications of the microscope, on the determination of the refractive index of minerals, and of the position of the axes of double refraction, and the study of meteorites, slags, and artificially fused rocks. But it was the characteristic of Sorby's mind always to seek for new veins of research rather than to bury himself in mines in which he had already broken ground.

In 1898, when receiving a portrait presented by his fellow-townsmen, he said: "The first thing is to find out some new subject or other, and open out some new line of investigation which is enough to occupy one all one's life. The difficulty is to avoid discovering new things and at the same time to work up old. I suppose that will go on to the end of the chapter, and I do not know that in doing so I am doing wrong, because possibly it is better to invent new things than to work up old ones thoroughly." These words exactly express the dominant sentiment in Sorby's mind during his whole life.

I fear that it must be confessed that, in the land of its birth, the new science of microscopical petrography made its way to the front much more slowly than in Germany. Sorby, it is true, almost from the first, found a trusty henchman and doughty champion in David Forbes, who at the Geological Society and elsewhere was always ready to take up the cudgels in Sorby's defence when, as was frequently

the case, the new method was assailed or ridiculed. But Forbes wrote little on the subject except his paper on the Igneous Rocks of South Staffordshire in 1866,[1] and some articles in popular journals, describing the method and its application. He made an extensive collection of some thousands of rock-sections, however, which is now preserved in the Manchester University.

In 1864 I went to Sheffield to take charge of a Chemical Laboratory in that town, and had the great privilege and pleasure of making the acquaintance of Sorby. He had then just been led by the study of meteorites to devote his attention to the microscopical character of irons and steels—a research as pregnant with results of technological value as his earlier work has been prolific in scientific developments. I was able to supply him with analysed specimens for his work, and he in return taught me to make and use microscopical sections of rocks. It is interesting to recall the simple methods he employed in those days. A chip broken from the rock to be studied was roughly reduced to a flat-sided fragment, by the aid of a grindstone of coarse sandstone. The subsequent work was done by cementing on a little square of plate glass, and then rubbing on laps with emery and afterwards on hone-stones. Sorby had an amusing faith in the virtue of the skin of his thumb for putting a final polish on the sections!

After joining the Geological Survey in 1867, I sought to utilize the methods taught me by Sorby, and prepared a paper on the "Origin of the Northampton Sand," which was read at the Geological Society on March 16th, 1869; it was there very kindly received and ordered to be printed. But the permission to publish was afterwards withdrawn by the authorities, and the paper did not appear till six years afterwards, when it was printed, but without illustrations, in the Survey Memoir I wrote on the Geology of Rutland (1875). Two others of my colleagues at that time, James Clifton Ward and Frank Rutley, also devoted themselves to microscopic work, but with little more encouragement than myself.

In 1869 Samuel Allport commenced his valuable series of papers on Microscopical Petrography, and in the following year John Arthur Phillips followed suit. Allport led Professor Bonney to take up the subject, and I need only refer to the great work accomplished by himself and his numerous pupils, as establishing the use of the method in this country.

It may be interesting, in concluding this sketch of the history of the origin of Microscopic Petrography, to state that, 58 years after the publication of Sorby's first paper on the subject, the geologists of all lands, who had assembled to celebrate the Centenary of the Geological Society, determined to send their greetings to the veteran investigator to whom they owed so much, and who then lay on his deathbed. Professors Iddings, of Chicago, and Lœwinson-Lessing, of St. Petersburg, requested Professor Zirkel and myself, as Sorby's oldest friends, to draw up an address to him, and this was signed by the President of the Society and those who had specially devoted themselves to Microscopical Petrography. The following is a copy of the address:—

[1] Geological Magazine, Vol. III. 1866, pp. 25–27.

"To the Father of Microscopical Petrography.

"We the undersigned, assembled to celebrate the Centenary of the Geological Society of London, desire to unite in expressing our profound conviction of the important service rendered to the branch of science which they cultivate by Dr. Henry Clifton Sorby. They deplore the circumstances which prevent him from joining them on this occasion, but beg to be allowed to assure him of their great admiration of his life's work, of their filial regard, and deep affection. They rejoice to know that he still finds consolation and happiness in his labours of love in connection with the promotion of scientific research and education.

"Archd. Geikie, P.G.S.

F. Zirkel, Leipzic.	J. W. Judd, Kew.
W. J. Sollas, Oxford.	J. P. Iddings, Chicago.
W. C. Brögger, Kristiania.	T. G. Bonney, Cambridge.
Whitman Cross, Washington, D.C.	F. Loewinson-Lessing, St. Petersburg.
Frank D. Adams, Montreal.	A. Harker, Cambridge.
F. W. Rudler, London.	T. McK. Hughes, Cambridge.
H. Arnold Bemrose, Derby.	J. W. Evans, London and Bolivia.
A. Wichmann, Utrecht.	Grenville A. J. Cole, Dublin.
A. Lacroix, Paris.	F. H. Hatch, Johannesburg.
H. A. Miers, Oxford.	J. W. Gregory, Glasgow.
J. S. Flett, London.	G. T. Prior, London.
J. J. H. Teall, London.	Hans Reusch, Kristiania.
C. Barrois, Lille.	C. Vélain, Paris.
G. F. Becker, Washington, D.C.	W. W. Watts, London."

From the dinner given to the assembled geologists by the Geological Society Club at its Centenary Meeting a telegram of recognition and condolence was also sent to their veteran associate, confined to a sick-room, and these marks of esteem and affection afforded him intense pleasure.

Many other problems of geological science were attacked by Sorby, during his long and busy life, with more or less success. Among these we may notice the pseudomorphous origin of the Magnesian Limestone and Cleveland Ironstone, the nature of the Coccoliths in the Chalk, the origin of Cone-in-cone structure, the mode of formation of impressed pebbles, many questions connected with denudation and the deposition of rocks, the formation of river terraces, and practical enquiries with respect to water supply and the contamination of rivers by sewage. Even in those cases where his solution of difficulties may not produce conviction in the minds of the readers of his papers, they cannot but be impressed by the ingenuity of the methods of inquiry which he devised.

But Sorby's work was by no means confined to geology. Scarcely any branch of knowledge or question of scientific interest escaped his attention. The use of the spectroscope in connection with the microscope; the nature of the colouring matters in blood, hair, foliage, flowers, bird's eggs, and minerals; meteorological problems of all kinds; improvements in blowpipe analysis and in the methods of detecting poisons, were among the subjects treated of in papers written by him between 1860 and 1879. In this latter year, after the death of his mother, Sorby, who had removed from Woodbourne to Broomfield in Sheffield in 1853, bought a yacht, and from that time forward spent nearly half the year on the water. His yacht, the "Glimpse," was, however, nothing but a floating study and laboratory, which enabled him to widen the sphere of his researches and find new

fields of investigation. Archæological studies among the churches of East Anglia; the evolution of mythical forms of animals in ancient church architecture; Roman, Saxon, and Norman structures, and the bricks employed in each of them, were among the subjects which engaged his attention; while enquiries among old manuscripts in the British Museum, the collection of ancient books and maps, and the study of Egyptian hieroglyphics were among his amusements. His short cruises around the coast were devoted to the collection of marine plants and animals, the preparation of catalogues showing the distribution of the marine flora and fauna, and the devising of methods for preserving plants and animals with their natural colours and exhibiting them as transparent objects; and in this he attained a remarkable success.

Those who had the pleasure of knowing Sorby in his home at Sheffield or on board his yacht can never forget the simple and lovable character of the man, and the devotion shown to him by his servants and sailors. The almost hermit-like seclusion of his earlier years had fostered many little amiable eccentricities in his habits, but his enthusiasm for science, his capacity for work, and his generous recognition of the labours of others were always conspicuous. Although, as we have seen, his great work in originating Microscopic Petrography received little notice for nearly twenty years, yet afterwards his labours were fully recognised. The Wollaston Medal of the Geological Society in 1869, the Boerhaave Medal in 1872, a Royal Medal in 1874, and the presidency, in succession, of the Microscopical, Mineralogical, and Geological Societies, with a doctor's degree given him by Cambridge, were among the honours which he received, while many foreign societies were proud to enrol him among their members.

Sorby was ever loyal to his native town of Sheffield, and was a warm supporter of its scientific and educational institutions. And Sheffield was justly proud of Sorby. It has been well said that what Priestley was to Birmingham, and Dalton and Joule to Manchester, Sorby was to Sheffield. From his youth up, he was a leading spirit at the local Chemical Society, the Sheffield Literary and Philosophical Society, and the West Yorkshire Geological Society. To the founding of Firth College in 1883 and its development into a University College, and finally into the University of Sheffield, he contributed unstinted labour as well as liberal support. By his will he not only enriches the City and University Museums with his valuable collections, but also founds a Chair of Geology in the Sheffield University.

The long and active life of research, during which nearly 250 papers[1] issued from his pen, found a fitting conclusion. In the Autumn of 1903, after returning from his Summer's cruise, he had a fall which produced partial paralysis. For many months he was unable to move himself in bed, but, bright and cheerful as ever, he enlisted the aid of his nurses, and continued his labours and the calculations based on five years' observations, writing with pencil while lying on his back. For a time he recovered so far as to be able

[1] An almost complete list of these papers has been published in the *Naturalist* for 1906; it was revised by Sorby himself.

to be wheeled about his room, and even to be carried into his garden and to be taken for carriage drives, but in January, 1906, he broke his leg, and was again entirely confined to his bed. The numerous pencilled letters that I received at this time showed unabated cheerfulness and delight in his work. On July 17th, 1905, he wrote: "What troubles me most is that I have such a vast lot of half worked-up scientific material, which takes me longer time than I *could* have expected to get into shape, and I fear I may never be able to finish it," and many subsequent letters expressed the same anxiety. He was able, however, to complete the paper "On the Application of Quantitative Methods to the Study of the Structure and History of Rocks," which is now being published by the Geological Society, to send a note to *Nature* on the colouring matter of flowers, and also to make some short communications to local journals. He was greatly cheered when he heard of the reception of his paper, and by the kind message from British and foreign geologists, to which he replied by sending copies of his portrait to those who had signed it.

Early in March Sorby's illness assumed a more alarming form, but he was cheerful and busily engaged in discussing scientific problems till within a few hours of his death, which took place on March 9th.

His best epitaph would be that written by himself: "My entire life has been spent either in scientific research or in preparation for it."

JOHN W. JUDD.

II.—Note on *Dinodocus Mackesoni*, a Cetiosaurian from the Lower Greensand of Kent.

By ARTHUR SMITH WOODWARD, LL.D., F.R.S.

IN 1840 Mr. H. E. Mackeson discovered a group of bones of a large reptile in the Lower Greensand near Hythe, Kent; and in the following year the specimen was briefly noticed by Professor (Sir Richard) Owen, who provisionally referred it to the genus *Polyptychodon*.[1] The fossil was presented by Mr. Mackeson to the British Museum, and ten years later the bones were described in detail by Owen,[2] who recognised that they agreed most closely with those of the Jurassic *Cetiosaurus*, but still thought they might belong to the "crocodile" whose teeth were known as *Polyptychodon*. Subsequent discoveries proved that *Polyptychodon* was a Pliosaurian, with limb-bones quite different from those of the Hythe fossil reptile, and Owen eventually realised that the specimen represented a species of Dinosaur, to which he gave the undefined name *Dinodocus Mackesoni*.[3] Without adding to our knowledge of *Dinodocus* Lydekker[4] placed it in the family Cetiosauridæ, while Marsh[5]

[1] Proc. Geol. Soc., vol. iii. (1841-2), pp. 525, 451; also Rep. Brit. Assoc., 1841 (1842), p. 197.

[2] "Rept. Cret. Foss." Mon. Palæont. Soc., 1851, p. 47, pls. xii, xiii, and woodcuts.

[3] H. G. Sorby, Quart. Journ. Geol. Soc., vol. xxxii. (1876), p. 436.

[4] "Hist. Brit. Foss. Rept." (1884), index to vol. ii. p. ix.

[5] "Catal. Foss. Rept. Brit. Mus.," pt. i. (1888), p. 136.

[6] Geol. Mag., Dec. III. Vol. VI. (1889), p. 296.

agreed that it was truly a Sauropodous Dinosaur, though of uncertain affinity.

The remains of *Dinodocus* are very fragmentary, and Owen records that owing to the difficulty of extricating them from the matrix they were "less characteristic" when they reached the British Museum "than when [he] took the description and sketches of them on the spot where they were found." The published description, in fact, gives no clear idea of the nature of the bones, and they can only be interpreted by discoveries which have been made since it was written.

The task of determining all the bone-fragments would be more laborious than profitable, but a careful study of the collection has proved that some of them can be united into two important elements, the humerus and the ulna, which are specially worthy of notice. These are now mounted for exhibition in the British Museum, and the humerus is represented in the accompanying text-figure.

Anterior aspect of left humerus of *Dinodocus Mackesoni*, Owen, from the Lower Greensand, near Hythe, Kent; ⅟₇ nat. size. [Brit. Mus. No. 14695.]

The upper half of the left humerus is shown in Owen's pl. xii, fig. 6, and described as a "fractured portion of the ilium." The bone itself is in small pieces, but there is a perfect mould of its anterior face in the hard Greensand matrix, so that at least this aspect can be completed in plaster. The lower half of a humerus is described and figured by Owen (*loc. cit.*, p. 48, pl. xii, fig. 1) as "lower end of shaft of femur"; but its surface is so much fractured and the distal end is so incomplete that it is not easy to determine whether the specimen belongs to the right or to the left side. On the whole, I am inclined to refer the bone to the right side, and have reversed the drawing of it in the accompanying figure. The two halves do not quite meet in the middle, the lower fractured end having been ground to display the nature of its cross-section. As remarked by Owen, the bone is solid, but the cancellous interior is of so open a texture that it might readily disappear in a fossil. The extreme length of the humerus must have been originally about 1·25 m., the width of its upper end 40 cm., and the width of its lower end not less than 30 cm. Its upper end is deeply concave on its anterior face, the deltoid crest being specially prominent. The shaft is slender, and the lower end, which lacks a few centimetres in the fossil, shows the usual prominence on the anterior face above the outer condyle.

A fragment of the upper end of the right humerus fits on the impression of its anterior face, which is correctly identified by Owen (loc. cit., pl. xiii, fig. 2, H).

Impressions of the right ulna and radius are preserved on the slab of Greensand described by Owen as exhibiting the shaft of a tibia and the lower end of a fibula (loc. cit., p. 49, pl. xiii, fig. 1). The ulna, which seems to lack only a short piece at its upper end, is a relatively stout bone about 60 cm. in length. Its upper portion is trihedral, with each of the three faces a little indented in the middle and measuring respectively 13, 15, and 17 cm. across. One view of it is drawn, upside down, in Owen's pl. xii, fig. 2, as a "lower end of shaft of humerus." A fragment of this region, showing the posterior indented face and two angles, is also represented in cross-section by Owen in his text-fig. 2, p. 50, as if it were complete, while the extent of the central loose tissue is hypothetically and erroneously shaded. Further down the cross-section is nearly as shown in Owen's text-fig. 1, p. 50. The distal end, which is complete and exhibits the usual pitted surface for a cap of cartilage, is represented by Owen in his text-fig. 6, p. 51, while the cross-section 15 cm. higher up is given in text-fig. 7, p. 51. The bone is less expanded at the upper end than in *Cetiosaurus* and *Morosaurus*. The radius itself is not preserved, and only the upper half of it is seen in impression. It evidently conforms to the Cetiosaurian pattern.

Of the other fragments of *Dinodocus*, it suffices to remark that none of them are metatarsals or other foot-bones. The specimen shown in Owen's text-figs. 10 and 11, p. 52 (also in pl. xiii, fig. 5), suggests the distal end of a fibula.

It is thus evident that *Dinodocus* is a large Sauropodous Dinosaur with a remarkably slender fore-limb. In its slenderness the humerus differs from that of *Cetiosaurus* and *Morosaurus*, while agreeing exactly with the Wealden humerus named *Pelorosaurus* by Mantell.[1] There is, in fact, no justification at present for regarding *Pelorosaurus* and *Dinodocus* as distinct genera. As already remarked by Seeley,[2] the Pelorosaurian humerus probably belongs to the same reptile as the Wealden vertebræ named *Ornithopsis*. The latest large Sauropodous Dinosaur seems, therefore, to have been more slightly built and more active on land than the *Cetiosaurus* of earlier date.

III.—On Changes of Level and the Production of Raised Beaches.

By T. F. Jamieson, LL.D., F.G.S.

I HAVE occasionally drawn attention to the effect produced on the relative level of sea and land by variations of pressure on the surface, such as would be occasioned, for example, by the increase or diminution of the loads of ice which existed during the Glacial period. I argued that the position of the surface must be always tending to an exact equilibrium between the upward and the downward pressure, and that any variation in the superincumbent load must result in some

[1] Phil. Trans., 1850, p. 379.

[2] Quart. Journ. Geol. Soc., vol. xxxviii (1882), p. 371; also Geol. Mag., Dec. III, Vol. IV (1887), p. 479.

change, however small, in order to rectify the balance. For if the balance was not perfect, motion must necessarily ensue, either up or down as the case might require.

The earth is such a large solid mass that we are apt to look upon it as perfectly immovable and rigid, and for all practical purposes no doubt it may be so considered. But in the great operations of nature with which geology has to deal such is not the case, and changes of pressure so small as to produce no visible effect to ordinary observation will, when continued for thousands of years, occasion changes that are manifest to all. In the following remarks we wish to draw attention to some results that have not, apparently, attracted the notice they deserve.

In a recent paper[1] I mentioned that one of the most obvious effects continually in progress is the denudation of the land by rain, rivers, and glaciers. These are always at work, wearing away the surface and transporting material down to the sea. Here, therefore, we have a process constantly going on which tends to lessen the weight of the land so that it will no longer balance the upward pressure; consequently the land will be forced up, and this rise of the land will help to compensate for the denudation which would otherwise in course of time tend to level down the continents altogether.

From the amount of sediment supposed to be annually carried into the sea by the Mississippi, Croll calculated that on an average about one foot in depth over the entire surface of a continent would be worn away in the course of 6,000 years.[2] Of course, this is only a very doubtful approximation, for the annual quantity of sediment carried into the sea by a large river is a matter very difficult to ascertain with any approach to accuracy; but it will serve to show the direction in which things are moving. The denuding action will evidently go on most energetically where there is a heavy rainfall and a rapid slope on the surface. The earth's action may be compared to that of a spring of enormous strength, on which the surface load exerts a downward pressure. When we lessen the pressure on this spring the result must inevitably be a rise, which will show itself in a change of the relative level of sea and land; and here comes in the point to which we desire to draw attention. The raised beaches observed on so many coasts may probably find their explanation in this action; but I am not aware that such a connection has ever been mooted.[4] Upheavals by volcanic action and obscure subterranean forces have been invoked, but no relation has been drawn between the existence or the varying level of these beaches and the denudation of the adjoining lands, whereas an interesting connection of this nature, I think, may be pointed out.

Taking the case of Scotland, we have raised beaches all round it, and I have elsewhere[5] endeavoured to show that on the east side, as

[1] Ibid., p. 486. [2] Geol. Mag., November, 1905, p. 485.

[3] Lyell, "Student's Elements of Geology," 2nd ed., p. 91.

[4] [See papers by Dr. C. Ricketts, "Subsidence Effect of Accumulation"]; Geol. Mag., 1872, p. 119; 1873, p. 141; 1883, p. 98; 1885, pp. 502, 548, etc. J. S. Gardner, op. cit., 1881, p. 241 and Plate, p. 289. Encl. Geol. Map.

[5] Journ. Geol. Soc., vol. xxi (1865), p. 190; Geol. Mag., January, 1906, p. 23.

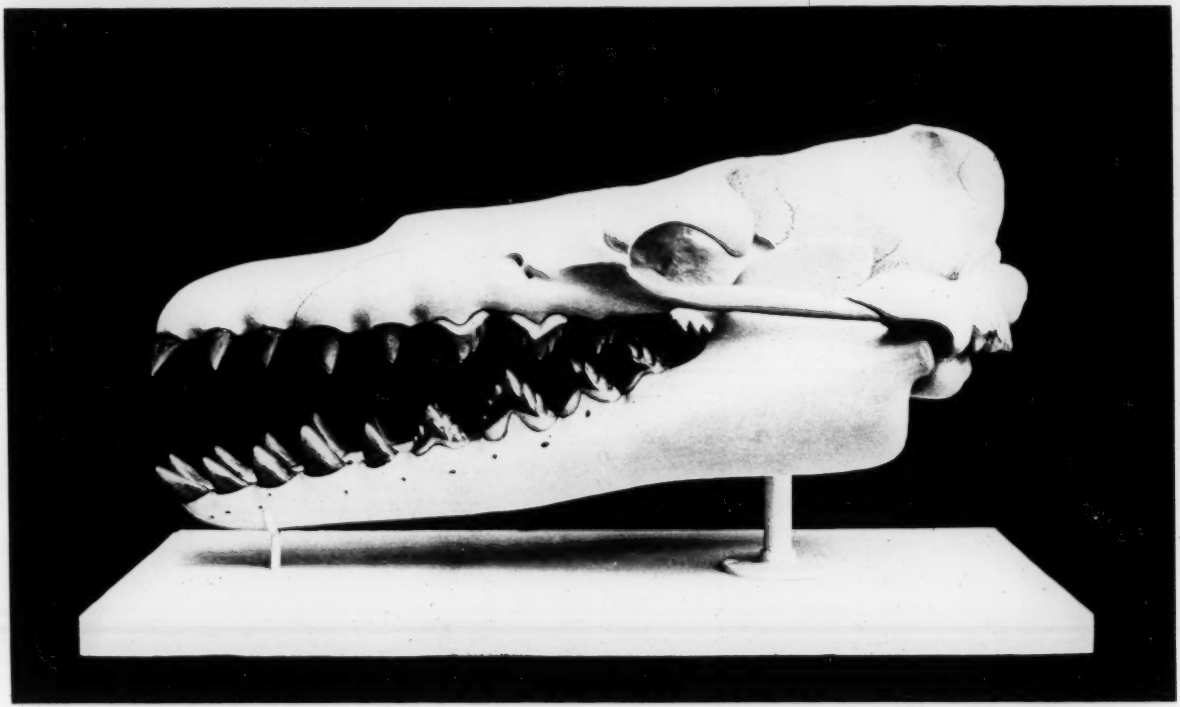
we trace the beach northward, the elevation gradually lessens from about 30 feet along the Firth of Forth to about 17 feet at Montrose and 8 feet or so at Aberdeen; a result which harmonizes with the smaller denudation that we might expect from the lesser rainfall along the valleys as we go north. In tracing the beach inland along the Forth we find its elevation increasing somewhat as we go up, and here again the result harmonizes with the theory. Again, on the West of Scotland we have higher beaches corresponding to the heavier rain along that side of the country. In the Shetland Islands, on the other hand, Messrs. Peach and Horne[1] particularly remarked the entire absence of any raised beaches. Now this is just the very thing we should expect on the theory here advanced, for the denudation caused by the rainfall there must be too slight to cause any noticeable rise. Islands, however, close to a mainland or continent would probably move up or down with the adjoining land, for unless they were some distance off they probably would not move independently. But the absence of these beaches in Orkney, and more particularly in Shetland, is an interesting and important fact which harmonizes so well with the explanation now offered that I am inclined to think this theory may prove to be the true one. Indeed, when one considers the frequent occurrence of raised beaches along the coasts of the world it seems difficult to account for them so well in any other way; for I fail to see how such widespread elevations of small amount could be effected all along the margins of our continents by the causes commonly assigned, whereas the denudation everywhere going on by rain and rivers is just such a universally present action as we require. Without the slow continuous rise of land thus brought about, the permanence of continents is not so easily explained.

The constant denudation by rain and rivers must inevitably lessen the downward pressure which the land exerts on the upward force that balances it, so that a rise must ensue, otherwise the equilibrium between the two antagonistic forces could not be maintained. Moreover, some lateral movement or pressure from beneath the sea-bottom towards the land would seem to be another necessary consequence, in order to replace the mass of matter removed by denudation and to make good the density lessened by the rise of land.

Raised beaches seem to occur all round Ireland, and Professor Hull tells us (in his Physical Geology of that country, 2nd ed., p. 143) that on following them from Antrim southward towards Dublin their elevation is found to decrease from the north to the centre of Ireland. This also is what might be expected, seeing that the rainfall decreases in the same direction. It would be desirable, however, to test the matter by observation on small islands, like the Azores and St. Helena, far off from any coast. In such cases there should be little evidence of recent raised beaches, although elevations of course might happen from causes entirely different from those we have been considering.

The continual accumulation of sediment brought down into the ocean by rivers must augment the load upon the sea-bottom and cause it to sink. This increase in the downward pressure, as already stated,

[1] Journ. Geol. Soc., November, 1879, p. 819.



Restored model of the Skull and Mandible of *Prozeuglodon atrox*, Andrews. About $\frac{1}{6}$ nat. size.
Middle Eocene: Fayum, Egypt.

would tend to generate a lateral subterranean movement, or squeeze towards the land; for resistance in that direction would always be diminishing owing to the lessened pressure exerted by the rising land, which would lower the density immediately beneath it. Some evidence of such movements in former times ought to be found in the strata of the earth, for actions of this sort must have taken place ever since rain and rivers began their work upon the globe.

IV.—Note on a Model of the Skull and Mandible of *Prozeuglodon atrox*, Andrews.

By C. W. Andrews, D.Sc., F.R.S., British Museum, Natural History.

(PLATE IX.)

During the last few years several papers have been published which throw much light on the early history of the whales, a matter about which there have been great doubt and difference of opinion. Two important points appear to have been settled: first, that the Zeuglodonts (*Archæoceti*) are descended from the primitive group of land-carnivores, usually known as the Creodonta, and, second, that the Toothed-whales (*Odontoceti*) are really derived from the Zeuglodonts. On this second point there may still be room for doubt, although in the opinion of the present writer the evidence brought forward by Professor Abel[1] in several papers, is at least sufficient to demonstrate the extreme probability that the Archæoceti are really ancestors of the Odontoceti. The origin of the Baleen-whales (*Mystacoceti*) is still obscure, but the fact that numerous true teeth are found in the unborn young, points to the probability that these animals also may have originated from the same, or a closely related stock as that from which the Odontoceti have descended.

The series of forms linking the Zeuglodonts to the terrestrial Creodonts has been discovered quite recently in the Middle Eocene deposits of Egypt. The earliest type is from near the bottom of the Lower Mokattam series (Middle Eocene) of Cairo: this animal, which has been described by Professor E. Fraas[2] under the name *Protocetus atavus*, is known from a nearly complete skull and some cervical vertebræ. The skull, which is about 60 cm. in length, much resembles in its general structure that of *Prozeuglodon* (see Plate IX or *Zeuglodon*, but has a rather more slender snout, with the nostrils situated relatively farther forward than in the later forms. The full Eutherian dentition (i. $\frac{3}{3}$, c. $\frac{1}{1}$, pm. $\frac{4}{4}$, m. $\frac{3}{3}$) is present. The sectant premolars and molars show no trace of the serration of their edges so characteristic of the later Archæoceti, but are much like those of a Creodont of the Hyænodont group; the third and fourth premolars have large inner (third) roots, while the same seems to be

[1] "Eine Stammtypus der Delphiniden aus dem Miocän der Halbinsel Taman": Jahrb. der k.k. geol. Reichsanstalt, vol. iv, pt. 2 (Vienna, 1900), p. 375.

"Die phylogenetische Entwickelung des Cetaceengebisses und die systematische Stellung der Physeteriden": Verhandl. d. deutsch. Zool. Gesellschaft, 1905, p. 81.

[2] "Neue Zeuglodonten aus dem unteren Mitteleocän von Mokattam bei Cairo": Paläont. Abhandl., N.S., vol. vi (1901), p. 199.

the case with at least the first and second molars. The molars are crowded together at the back of the jaw and seem already to be undergoing the degeneration which in later forms leads to the loss of at least some of them. The axis vertebra is very similar to that of a carnivore, and the centra of the other cervicals are not shortened up as in the later Zeuglodonts. Altogether *Protocetus* may be regarded as a Creodont that has become adapted to an aquatic life.

From beds of rather later age in the Fayûm Mr. Beadnell collected remains of another Zeuglodon, which has been described under the name *Prozeuglodon atrox*. Plate IX is a photograph of a model of the restored skull and mandible of this species, and gives a very good idea of its chief peculiarities. The model has been skilfully constructed by Mr. F. O. Barlow, mainly from a cast of the skull and mandible which are the types of the species, but some details were added from a less complete but comparatively undistorted specimen. The skull on the whole is quite Zeuglodon-like, but the snout is a little shorter than in *Protocetus*, and the nostrils a little farther back, though not so far as in *Zeuglodon*. There is a strong high sagittal crest, the tympanic bullæ are well developed, and the zygomatic arch is somewhat stouter than in later forms. The dentition appears to be exactly intermediate between that of *Protocetus* from the beds below and that of *Zeuglodon isis* from those above. The dental formula seems to have been i. $\frac{3}{3}$, c. $\frac{1}{1}$, pm. $\frac{4}{4}$, m. $\frac{3}{3}$ (?). The incisors are conical, sharply pointed teeth, separated from one another by moderate intervals. The canine is larger than the incisors in front and the premolar behind, probably a relic of the Creodont condition. The first premolar is a single-rooted tooth, and in one specimen it can be seen that it must have been preceded by a milk-tooth. The other premolars have the compressed serrated crowns characteristic of the group. The second upper premolar has two roots, while the third and fourth have a large third (inner) root as in *Protocetus* and the Creodonts. The molars were probably two in number; it is not clear whether their posterior root was single or imperfectly divided into two. Another Creodont character in the upper jaw is seen in the presence of deep fossæ on the inner side of the premolars for the reception of the points of the lower teeth. None of the lower teeth have more than two roots.

In beds of about the same age as those in which *Prozeuglodon* occurs there are found two or three very large Zeuglodonts, one, *Eocetus Schweinfurthi*, E. Fraas, being likewise in many respects intermediate between *Protocetus* and *Zeuglodon*, while another, *Zeuglodon isis*, is, so far as known, close to the true Zeuglodonts. The occurrence of these large forms so early shows that specialisation in this particular direction was very rapid. In the upper beds of the Middle Eocene (Qasr-el-Sagha series) of the Fayum only true Zeuglodonts are found, differing in no important respect from the various species which at that time had already spread over most of the seas, remains having been found in Europe, America, and New Zealand.

The great rapidity with which both the primitive whales and the Sirenia seem to have become completely adapted to an aquatic life is very suggestive. In both cases these groups appear to have arisen

from terrestrial mammals during the Lower Eocene period, and long before the close of the Middle Eocene had become almost as completely adapted to an aquatic life as their descendants at the present day. It may be of interest to consider the reasons for this rapid change. In the first place it is pretty certain that at the close of the Mesozoic period all the groups of great marine reptiles had, for some unknown reason, become extinct, so that, excepting the fishes and a few Rhynchocephalian, no vertebrates inhabited the early Eocene seas. The consequence of this would be that if any terrestrial forms should adopt an aquatic life, the freedom from competition and, to some extent, from powerful enemies, would offer exceedingly favourable conditions for their rapid spread and multiplication in the seas, while the great development and differentiation of the land mammals at the same period would render the conditions of terrestrial life more and more exacting. Consequently, when the primitive swamp-loving Proboscidean ancestor of the Sirenia and the early Creodont from which the Zeuglodonts arose took to living in the water, everything was in their favour. The rapidity with which these animals became adapted to their new conditions of life is probably the direct result of the complete change in the mechanical conditions of life. For one thing, the limbs cease to support the weight of the body, which is now borne by the water in which it floats. On the other hand, the limbs are still used for propulsion, and consequently there is a forward thrust at their proximal ends. The consequence of this thrust in changing the structure of the pectoral and pelvic girdles has already been discussed in the case of the Plesiosaurs. The manner in which movement through the water is affected of course differs widely in different groups of aquatic animals. Thus, in the whales it is by the fore-limb and a transverse tail-fin, the hind-limb being lost; in the Ichthyosaurs by both the fore and hind paddles, the former being the more important, and a vertical tail-fin; in the sea-crocodiles (*Metriorhynchus*, etc.) by the hind-limb and tail; and in the Plesiosaurs by the oar-like fore and hind paddles. Whatever means, however, is employed to propel the body through the water, during motion it is subjected to a pressure on its anterior end, more or less in the direction of the long axis, and during very rapid movement this pressure must be considerable. Most of the peculiarities of the skull of the whales seem to result from this new condition. In the first place, to facilitate passage through the water a more or less slender rostrum is as a rule developed, though in the later and larger forms of some of the groups it may be lost or masked by other structures. In the next place, the pressure seems to have brought about the spreading back of the posterior ends of some of the facial bones, so that the premaxillæ and especially maxillæ overlapped the bones behind to a great degree. The same force also may have had much to do with the shifting back of the external nares. The peculiarities in the structure of the cranial portion of the skull are also capable of explanation in the same way. The primitive whales seem to have had brains of considerable size, and the brain-case would be liable to distortion from continual frontal pressure. This pressure seems, for instance in *Phocæna*, to have resulted in the squeezing out of the parietals from the middle line, and the extension

back of the frontals to the supraoccipital and interparietal, which are greatly enlarged to resist the backward thrust. The shortening up of the Cetacean brain seems to be in part due to this compression of the skull and in part to the complete reduction of the olfactory region. The shortening and, in some forms, the fusion of the cervical vertebræ seem also to be a consequence of the same cause. The great size of many of the Cetacea is no doubt rendered possible partly by abundance of food and partly on account of the support of their weight by the water. It is very notable that some of the earliest members of the group, already in Middle Eocene times, attained very large dimensions, but in this case, as usual, it does not appear that these giants gave rise to any of the later stocks, which are derived from the smaller and more plastic members of the group.

No doubt the various changes above noticed may be regarded as entirely the result of selection acting on variations in the necessary direction, but the rapidity with which these changes took place and the apparent uselessness of some of them, at least, suggest, that in spite of generally accepted doctrine that acquired characters are not inherited, in some cases complete change of the conditions acting throughout the life of each individual for generations does actually give rise to and direct the modifications undergone.

V.—On some recent Wells in Dorset.

(Part I.)

By W. H. Hudleston, M.A., F.R.S., F.G.S.

THE requirements of towns, and even of camps, in the matter of water supply are so great nowadays that surface waters are avoided as likely to be contaminated, and there is consequently a great desire to rely on deeper sources. Quite an official literature has sprung up of late years, and important memoirs have been issued by the Geological Survey on the "underground sources" of several counties. So far as I am aware there has been no official memoir relating to the county of Dorset, and this probably arises from the circumstance that the artesian principle has not been made use of to any great extent until recently, although the Dorset syncline would seem to be eminently suitable for artesian wells.

Nevertheless, some important sinkings and borings have been executed in Dorset of late years, and these works, altogether irrespective of their economic importance, as yielding abundant supplies of good water, are of further interest to the geologist in that they afford evidence of the character and development of some of the Tertiary strata, which cannot otherwise be obtained. The Bagshot Beds of this county, for instance, have always presented difficulties to the stratigraphist, since few reliable outcrops can be obtained in the interior of the country on account of the yielding nature of the sands and clays of this formation. It is for these reasons that I venture to offer in the pages of the Geological Magazine an abstract of two papers which have already appeared in the Proceedings of the Dorset Field Club, the one relating chiefly to a deep but not artesian well sunk for the supply of the town of Wareham, and the other a paper

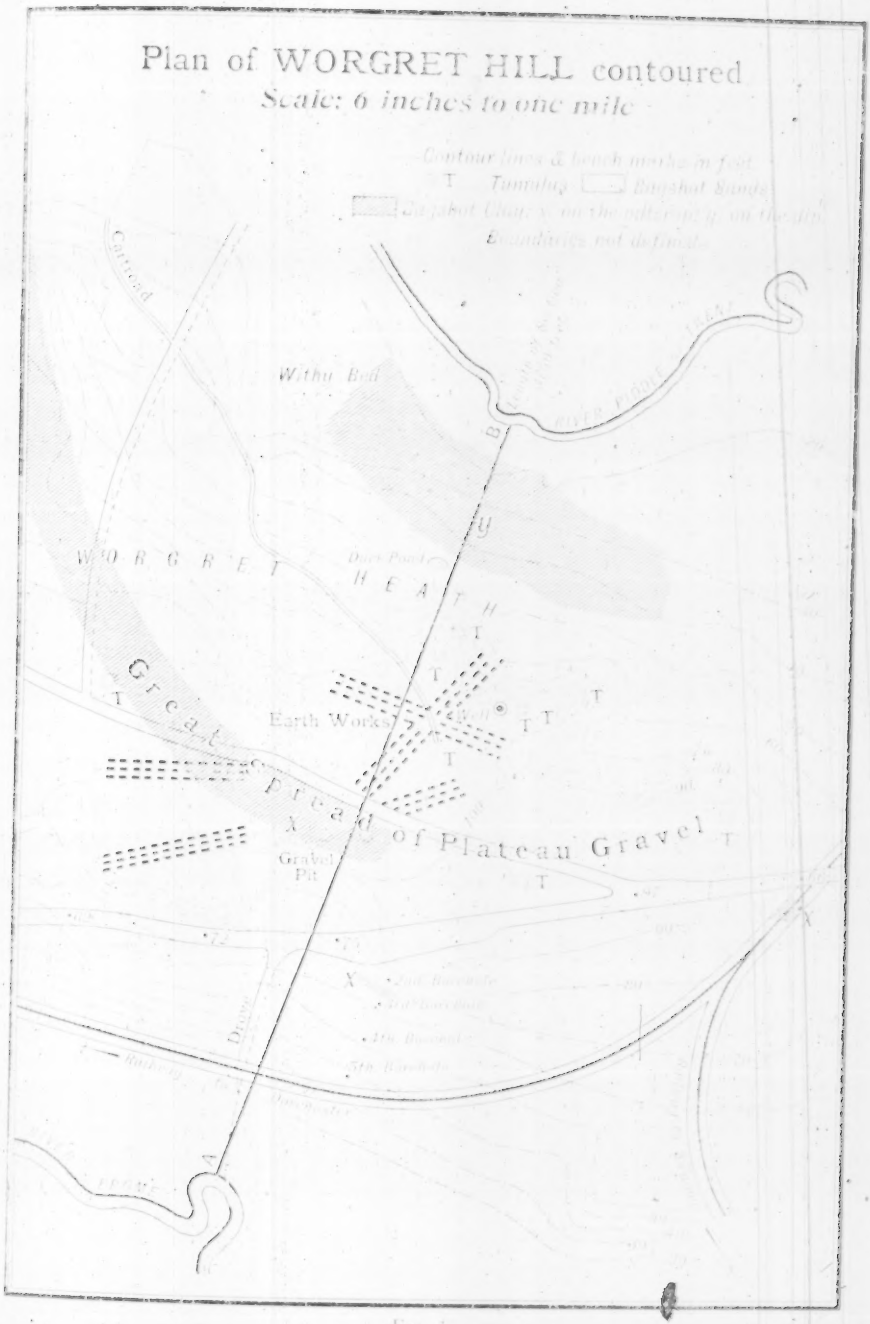

Plan of WORGRET HILL contoured
Scale: 6 inches to one mile
Contour lines & bench marks in feet
T Tumulus
Bagshot Sands
Withy Bed
WORGRET
HEATH
Earth Works
Great
Spread
of Plateau Gravel
Gravel Pit

FIG. 1.

dealing with artesian wells generally, but more especially with one bored at Bovington Camp in the Autumn of 1906.[1]

I. The Worgret Hill Well and Borehole.

Worgret Hill (see Plan, Fig. 1,[2] and Section, Fig. 2) is situated about one mile to the west of the town of Wareham, and is crossed by

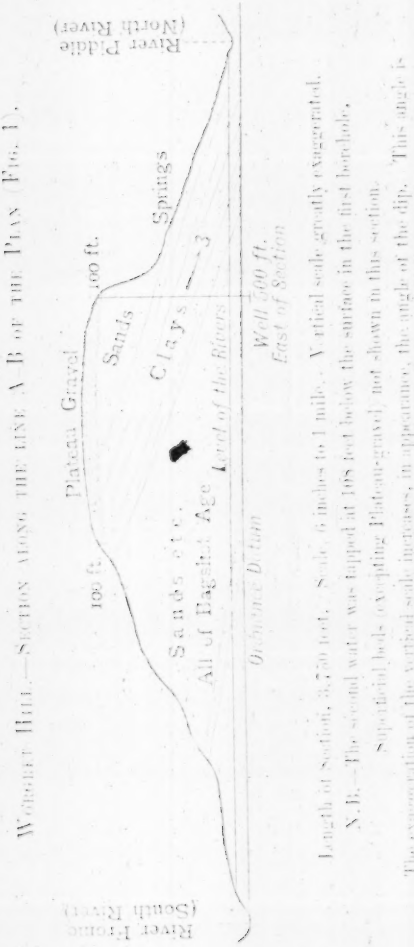


Fig. 2.

Worgret Hill.—Section along the line A B of the Plan (Fig. 1).

Length of Section, 3,750 feet. Scale, 6 inches to 1 mile. Vertical scale greatly exaggerated.

N.B.—The second water was tapped at 195 feet below the surface in the first borehole.

Superficial beds (excepting Plateau-gravel) not shown in this section.

The exaggeration of the vertical scale increases the appearance of the dip. This angle is believed to diminish in the direction of the Frome Valley.

(1) "Worgret Hill and the Wareham Water Supply": Proc. Dorset Field Club, vol. xxvii (1906). (2) "Artesian Wells in Dorset and elsewhere": ibid., vol. xxviii (1907). [1] By permission of the Council of the Dorset Field Club.

[2] The Ordnance 6 in. map is contoured at 50 and 100 feet. The intermediate contours on the Plan were fixed approximately by myself and Mr. Bloomfield during the Winter of 1907/08.

the high road from that town to Dorchester. To anyone coming from Wareham it presents the first sharp rise from the low platform on which Wareham is built,[1] and the contour map shows us that it consists of an elevated platform with steep sides, sloping to the south and north rivers respectively.

As regards its geological features, Worgret Hill may be said to occupy a central position in the great trough or syncline of Wareham,[2] being about equidistant from the outcrops on either side. Except for Plateau-gravel on the summit platform it consists wholly of clays and sands of the Bagshot series, and it is the alternation of these which constitute its water-bearing capacities (see Section, Fig. 2). These Bagshot Beds extend for an unknown depth downwards, and quite possibly hereabouts attain their maximum thickness so far as this part of Dorset is concerned.

In the year 1898 a trial borehole was made at Worgret by Messrs. Pike Bros., and in 1899 the sinking of the well commenced. After getting through the Higher Bagshot Clay Series an abundant supply of water was found in a coarse silicious sand with much 'lydite,' struck at about 198 feet from the surface, and this water rose to a level of 91 feet from the surface in the well. Borings were subsequently continued about this period to a depth of 121 feet from the surface.

In November, 1900, there was a fortnight's test-pumping, when the flow was found to be 94 gallons per minute. In August, 1901, the permanent pumps were fixed, and in November of that year a further test-pumping yielded 56,000 gallons of water in ten hours. There seems to have been some suspicion as to the turbidity of the water, and Mr. Chatterton, the engineer, then felt satisfied that if some turbidity still existed it could be got rid of by deepening the well.

On February 4th, 1903, an enquiry instituted by the Local Government Board was held at Wareham, in the matter of the application of the Town Council to borrow a certain amount for the purposes of a water supply. This was sanctioned in September, 1904, and the tender of Messrs. Docwra & Sons to carry out the works was accepted. These works consisted chiefly in making a reservoir on the top of Worgret Hill, and in laying the mains to and throughout the town of Wareham. During the operations Messrs. Docwra used a considerable quantity of water from the well, and it was found to be still turbid with much fine sand.

There was still some dissatisfaction at the turbidity of the water, and in June, 1905, cavities in the sides of the well had to be filled with gravel. It was also decided to start a borehole from the bottom of the well in the hopes of finding a more satisfactory supply of water. On October 7th Mr. Chatterton, the engineer, wrote to the effect that the test-pumping showed that the boring yielded practically no further supply of water. At that time the borehole had passed through the

[1] The cross roads in the centre of Wareham mark 214 feet above O.D.

[2] For a diagrammatic sketch of the Trough of Wareham see Proc. Dorset Field Club, vol. xxiii, p. 148.

second great Sand-series, and was already encountering some grey and mottled clays, which he conceived might indicate the presence of the Reading Beds, and that possibly the Chalk was not far off; after going through this Clay-series for 30 or 40 feet further, he began to have his doubts as to the position, since there was no change in the nature of the ground, the boring being still in the grey clay. It was pointed out that the samples brought up tallied with the regular pipeclay series of the Bagshots, and that the Chalk was still far distant. The boring was carried through these clays to a depth of 215 feet from the surface, and on October 30th operations were finally discontinued.

Worgret Well and Borehole.

Details of beds from 101 feet *above* Ordnance Datum to 114 feet *below* Ordnance Datum:—

			Thickness.	Depth.
			ft. in.	ft. in.
		Pleistocene.		
a.		Plateau-gravel	9 0	9 0
		Bagshot Beds.		
		A. Higher Bagshot Sand Series.		
		B. Higher Bagshot Clay Series.		
		C. Second Bagshot Sand Series.		
		D. Pipeclay Series.		
A (40 ft.)	*a*.	Fine dry sand, gradually getting coarser ...	28 6	
	b.	Sandy loam	6 0	
	c.	Fine dry sandy loam, white in colour	5 9	
	d.	Fine sand, waterlogged	6 0	46 0
		The Top Water.		
B (54½ ft.)		Loamy clay, gradually becoming more sandy towards the base. No divisions were made in this series	54 6	100 6
		Stems, leaves, and fruits were found in pale-coloured pipeclay below 82 feet.		
C (166 ft.)	*a*.	Streaky beds of sand and loam from one to three inches thick	1 6	
		The Second or Main Water. At 108 feet the water came in and rose to 91 feet.		
	b.	Coarse dark sand	4 0	
	c.	Coarse sand, getting finer below	9 0	121 0
		(Termination of the original boring.)		
	d.	Pyrites, sand, and wood	1 0	
	e.	Alternations of grey sands and clay	8 0	
	f.	Thick grey sand	12 6	
	g.	Alternations of grey sand with some grey clay ...	20 0	
	h.	Very coarse dark grey sand	3 6	166 0
D (49 ft. proved).	*a*.	Grey pipeclay, said to contain leaves in places	10 6	
	b.	Stiff yellowish clay, compact, and rather heavy, also mixed	5 6	
	c.	Mixed bluish grey and yellow clays, rather gritty	4 0	
	d.	Reddish ochry clay, staining the fingers like ruddle	1 0	
	e.	Additional boring not detailed. Terminates in grey pipeclay	24 0	215 0

In explanation of the above table, it may be stated there is no longer any idea of making use of the top water, and that all the

calculations as to supply refer to the second or main water. This is considered to be sufficient in amount for all the requirements of Wareham, but unfortunately it takes so long to clear from fine sand as to be detrimental to the pumps. It is worthy of note that the normal water-level in the well stands at a height of 91 feet from the surface. Pumping may lower the water-level in the well 15·97 feet below the surface, but no amount of pumping can reduce the water-level below this point. Hence Mr. Drew infers that there is a leakage in the upper six feet of water, but that below this horizon there is no lateral escape. In connection with this subject it may be useful to remember that the whole of the 62 ft. 6 in. of the Second Sand-series (C of the column) is saturated, and these saturated beds rest on the second Clay or Pipeclay series of the Bagshots (D of the column) at 166 feet below the surface.[1] The second water was first tapped in a waterlogged sand at a depth of 108 feet from the surface, and there is this anomaly in the situation, viz., that this water is much closer to the Clay-series (B), which holds down the water, than it is to the Clay-series (D), which holds it up. It may be that the proximity of a roof of clayey beds to the stratum from which the water is actually drawn has a tendency to increase the amount of fine sediment which hitherto has proved to be so prejudicial to this water.

The Plateau-gravel (x).—This is generally regarded as a Pleistocene formation, but is certainly one of high antiquity, since it apparently antedates the formation of both the valleys, viz., those of the Frome and Pydel, which flank the block of Bagshots on which it rests.[2] It is of some importance economically, since the best road-metal of the district is obtained from these beds.

A very interesting and instructive section of these beds was disclosed in January, 1905, during the excavation for the reservoir on the summit of Worgret Hill. The excavation was more or less a true square, and I selected the eastern side as a type of the whole (see Fig. 3, based on a photograph taken by Mr. Churchill). The face of gravel here is remarkably vertical, and the gravel holds together so well as to cause surprise to some of the workmen. The peculiar interest of the section at the reservoir arises from the discharged colour noticeable in the upper part of the Plateau-gravel owing to the action of peaty acids having dissolved out or reduced the colouring matter, chiefly iron and manganese oxides. This no doubt may be seen to a certain extent in most gravel-pits; but here a further feature has been produced, viz., the irregular piping of the yellow unreduced gravels by percolation from above.

Particulars of the Bagshot Beds.

The Higher Sand-series (A).—The general character of these beds on the surface is that of the ordinary pale-yellow Bagshot Sands of

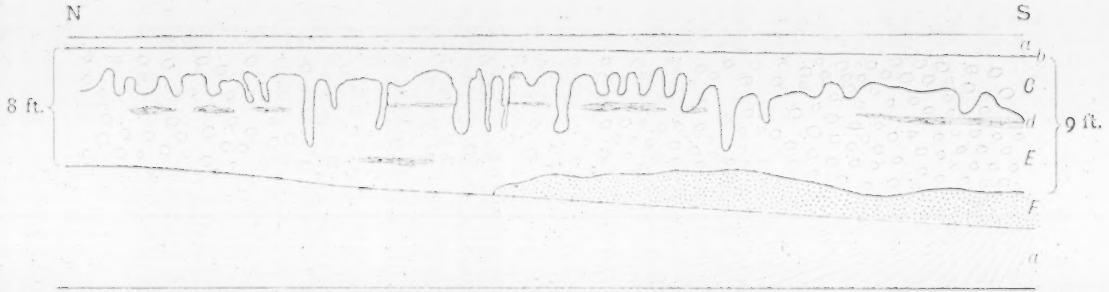
[1] The late Mr. L. W. Pike informed Mr. Drew that throughout the area of Furzebrook and Grange, where his operations for clay were carried on, he invariably encountered at the same level a body of water which he believed to be identical with that found in the well at Worgret.

[2] See Proc. Dorset Field Club, vol. xviii, pp. 129, 130, article by Clement Reid.

the district. The water-logged sands at the base (A, *d* of the column), described as fine in the section, are certainly coarse, where they are seen to come out on the dip slope, and contain much water (the top water).

FIG. 3.

EASTERN FACE OF THE EXCAVATION IN THE PLATEAU-GRAVEL FOR THE RESERVOIR AT WORGRET, JANUARY, 1905.



Explanation of signs.

a. Surface of the plateau.

b. Summit-line of the excavation.

C. Plateau-gravel, bleached by the action of peaty acids, *grey* in colour.

d. Lines of exceptional accumulation of black oxide of manganese.

E. Lower portion of the Plateau-gravel, retaining for the most part its original *yellow* colour, but irregularly stained with black oxide of manganese, and piped by the action which has altered the colour of the gravel above.

F. Bagshot sand *in situ*, on which the Plateau-gravel rests.

a'. Floor of the reservoir.

The Higher Clay-series (B).—The fruits and plant remains are approximately on the same horizon as those from Norden and Bournemouth.

The Second Sand-series (C).—The most interesting bed in this series is the one indicated in the table as C, *b*, which contains such a large quantity of water. This is composed of angular grains of a highly crystalline quartz; the larger fragments are dull or fatty, and range up to ¼ inch. There is also a considerable amount of dark-coloured silicious fragments, such as go under the general term of 'lydite.'

The Pipeclay Series (D).—As this group is only known from boring, the arrangement of the details is somewhat arbitrary since the several clays were much mixed. There can, however, be little doubt that series D represents the Pipeclay Beds of the northern and southern outcrops, though inferior to the clays of the southern outcrop in quality. Much the same varieties of clay as we find in the Creech district came up from the borehole, and there was no difficulty in recognising the greyish-white pipeclays alternating with the inferior or variegated varieties known in the workings as 'two-ball' clay.

"When we come to speculate on what lies below the termination of the borehole (215 feet from the surface), it is almost impossible to predict what may be the thickness of the remainder of the Bagshot Beds. Below the pipeclay series it is almost certain that another sandy series would be encountered as constituting the base of the formation, and there may be bands of iron grit such as occur on this horizon at many places in the Isle of Purbeck. None of the Government geologists, so far as I know, give us any assistance in estimating the thickness of the Bagshot Beds at their full development in Dorset.

"*The Lower Tertiaries.*—We may naturally conclude that both the London Clay and the Reading Beds will have to be encountered ere the Chalk can be reached. Very little is known about these beds, which are best studied, perhaps, on their outcrop in the Wool district. In a borehole section it may not be very easy to distinguish between Bagshots and London Clay, as the latter formation in this country consists largely of sand. Probably the most distinguishing feature of the London Clay is the amount of black flint pebbles which it contains, and which are sometimes cemented by iron-oxide into a most intractable conglomerate. The Reading Beds are also mainly sandy, but side by side with these sands are developments of mottled clays largely used for brick-making. A total thickness of 100 feet for the London Clay and Reading Beds is, perhaps, fairly approximate.[1] It is quite possible that some of these Lower Tertiaries may contain good water-bearing beds."

The main interest, from a geological point of view, consists in the estimated thickness of the unproved Tertiary beds down to the Chalk. As regards the Bagshot portion of this unknown quantity, I may refer to two short memoirs by the Government Surveyor, Mr. Clement Reid, F.R.S., "Geology of the Country round Bournemouth" (1898) and "Geology of the Country round Dorchester" (1899), and although in the question of the total thickness of the Bagshot system in the

[1] This estimate was subsequently increased to 145 feet.

Wareham district we have no direct information from Mr. Reid, yet the following passage (p. 25 of Dorchester Memoir) may possibly throw some light on the as yet unproved strata below the termination of the Worgret borehole: "Close to Organ Ford, and for nearly a mile to the westward, white pipeclay mixed with carbonaceous clay can be seen in the road south of the stream. This bed is apparently equivalent to the stratum that is worked at its southern outcrop round Creech, though at its northern outcrop it does not appear to be more than 50 feet above the London Clay." The statement is important as showing that in the neighbourhood of Organ Ford, rather more than three miles due north of Wareham, the Pipeclay series, towards its northern outcrop, is quite low down in the Bagshot system. Now, when we come to consider the bearing of these facts on the hypothetical estimate of 85 feet for the "Remainder of the Bagshot Beds unproved," as given for series E in a tabular column attached to the Report,[1] it seems to encourage the belief that, when the boring rod reached 215 feet from the surface of the Worgret Hill plateau, 85 to 100 feet would be a fairly liberal estimate of the thickness of the remainder of the Bagshots. The chief element of uncertainty lies in the fact that the Pipeclay series was not gone through, but we may assume almost with certainty that a *third* Bagshot Sand-series, with a development of 60 or 70 feet, would still have to be encountered ere the Lower Tertiaries were reached.

(*To be concluded in our next Number.*)

VI.—On a Method of Splitting Ironstone Nodules by means of an Artificial Freezing Mixture.

By L. Moysey, B.A., M.B., B.C., F.G.S.

MOST geologists who have had anything to do with the ironstone nodules in the Coal-measures have been struck by their perverse and refractory behaviour under the hammer. How one nodule will refuse to break under the most well-directed blows, and another, though breaking easily, will exhibit to the disappointed collector a clean bright surface of clay-ironstone, without a trace of that organism that he hoped, and almost had a right to expect, was there. It seems therefore necessary to find some other and perhaps less violent method of breaking them.

The nodules used for the following experiments were taken from a now disused brickfield situated near Ilkeston, in Derbyshire, on the Shipley Hall estate, owned by E. M. Mundy, Esq., the horizon being just below the *Top Hard Coal*. The clays of this pit, unlike most of the South Derbyshire Coal-measure clays, teem with nodules for the

[1] This refers to the Report made by Mr. Hudleston to the Town Council of Wareham as to the advisability of continuing the boring. In this Report the particulars of the work already executed are given in a tabular form together with an approximate estimate of the probable thickness of the remaining Tertiaries ere the Chalk was reached. The total thickness of the beds above the Chalk in Worgret Hill was finally estimated at 425 feet.

most part symmetrical, with smooth surfaces, ranging in size from a small orange to a large dinner plate, and in shape oval, round, or flattened. Almost every nodule which was found naturally cracked contained some organism or another in a good or bad state of preservation; it is therefore justifiable to assume that those nodules which are still intact also contain organisms. Many of these stones have been broken by mere brute force, always with the disappointing result of obtaining a clean fracture without any sign of fossil; or perhaps the surface showed that a fossil was there, but that it was completely ruined by being broken across in a plane a little above or a little below its actual position in the nodule. Heating them to red heat and plunging them in water was then tried; but this apparently was a too violent method, as the stone when it did break did so into small fragments quite independent of the position of the fossil. The method also is not unaccompanied with danger, as the stones are apt to explode with great force, either in the fire or when plunged into water.

During this Winter, however, several nodules, most of which had been subjected to severe hammering to no purpose, were brought home and frozen, with, as it seems to me, fairly good results.

Nothing of novelty, however, can be claimed for this method, as it is probable that many geologists have made use of a freezing mixture in this connection; though there is scanty, if any, literature on the subject, the late Professor Constantin Baron von Ettingshausen of Graz in Austria practised it successfully on Tertiary shales containing fossil plant-remains.

The method now adopted was to keep the nodules soaking in water, then to place them in a tin cannister, and surround the tin with an ice and salt mixture in a pail. After leaving them in the cold atmosphere thus generated for forty-eight hours, it was found that most of them showed a crack running right round them. On thawing, some were found to be cracked right through, and a light tap with a hammer split them and revealed, in many instances, a very perfect fossil. Others, however, though appearing to be cracked, simply shelled off an outer husk of disintegrated stone, leaving a hard solid core as refractory as ever, which, on again freezing and thawing, sometimes split and sometimes cast off another shell.

From these failures it was thought that perhaps the water did not penetrate into the heart of the nodules in every instance, so several nodules were heated gently to drive off the imprisoned air by expansion, and were then plunged, while hot, into water. After this treatment, in many instances, otherwise refractory nodules were successfully split.

A curious secondary result of these experiments has been the discovery of a greater proportion of rare fossils in the nodules thus artificially split than in those found naturally broken in the clay-pit. Out of some ninety nodules cracked by freezing, there have been found three specimens of *Belinurus*, one *Palæocaris*, two specimens of a new shrimp-like animal, and one possibly new animal which may turn out to be a complete but diminutive example akin to the *Arthropleura armata* of Jordan from Saarbrücken.

The pit has yielded many rare fossils; for instance, two specimens of *Fayolia*, ten of *Palaeoxyris*, ten of *Eurypterus*, eight or nine of a new shrimp-like animal, fourteen of *Belinurus* and *Prestwichia*, and one of a true insect. But these have been collected (except in the case of the shrimp-like animal, which has been found mostly during the last year) during a space of time extending over the last five years, and in the proportion of one rare animal to several thousand stones examined.

From the ninety nodules split by freezing were obtained—

18–20 nondescript plant-remains,	6 ferns,
1 root-filament,	1 *Cuia*,
17 *Annularia* and *Calamocladus*,	5 *Belinurus*,
1 *Sphenophyllum*,	1 *Palaeoxyris*,
3 *Lepidophyllum*,	1 ? *Arthropleura*,
1 Calamite,	2 shrimp-like animals,

the remainder splitting badly or containing unidentifiable remains. Of the naturally split stones found in the clay-pit, the commonest organisms would certainly be the ferns; second would come the nondescript plant-remains, that is, a jumble of stems, fern-leaves, etc.; third, *Calamocladus*, etc.; and fourth, *Calamites*.

Of course, the extraordinary proportion of rare fossils may be due to chance, or, more possibly, to that factor combined with an instinctive collection of such nodules as are likely to contain good specimens. To this instinctive selection may be attributed, to a great extent, the undue preponderance of *Calamocladus*, etc.; as these plants are usually, in this pit at any rate, contained in small symmetrical oval nodules, which would be more likely to be brought home than rough irregular ones. But it is conceivable that those fossils, like fern fronds or stems, which have a fairly broad surface and a layer of coaly material more pervious to water than the stony matrix, would be easily cracked by the recurrent frosts of Winter; and that those of an animal nature which have a chitinous covering more durable than the stone, or at any rate have no coaly film to let the water into the plane of the fossil, and those plant-remains that do not show a large flat surface inside the stone, would be the ones that would resist longest the natural disintegrating agencies. Hence it is possible that those nodules which resist the longest may be just those which it would be most worth while to persevere in cracking; and in this way the poverty of the faunal record in most coalfields may prove to be more apparent than real.

REVIEWS.

I.—Physiography. By Rollin D. Salisbury, Professor of Geology and Head of the Department of Geography in the University of Chicago. 8vo; pp. v + 770, with 24 plates and 707 text-figures. London: J. Murray, 1907. Price 21s. net.

PHYSIOGRAPHY owes much to the enthusiasm and industry of its exponents in North America, of which the big volume before us is one more token. The science has ill-defined borders which can be to some extent rearranged at will to suit the scope of its demonstrator. But although so eminent a geologist, Professor Salisbury

exerts restraint and skill in the subordination of his geological knowledge to the strict requirements of his subject, which, in his introduction, he defines thus: "Physiography has to do primarily with the surface of the lithosphere, and with the relations of air and water to it. Its field is the zone of contact of air and water with land, and of air with water" (p. 1). And in discussing the relation of the science to geology, he adds: "Geology has to do with the history of the earth; while physiography has to do with a late chapter only of that history,—the history of the present surface."

As thus defined, physiography is a sufficiently vast subject, dealing always with phenomena and processes that embrace the whole earth in their scope. Its far-reaching conceptions rise clear above the tangle of minute detail so repellent to the impatient imagination; and if in these days of specialized education there should ever be attempted a course of scientific instruction for budding poets and other aspirants in imaginative literature, assuredly physiography, equally with astronomy, should be one of the subjects to be taught. And really, when one thinks of it, the want of such a course is serious; for, more than ever, we need the stimulus of an inspiriting utterance of our new ideas in perfect form, while the poets, mostly helpless from imperfect education, can still only harp upon obsolete instruments, or set our teeth on edge when they venture to touch the new strings. Nor, if the imaginative person can keep pace with the strenuous American student, need his grounding in physiography take long, for, in the preface to this comprehensive book, we read that the work outlined in it "is essentially the work covered in the University of Chicago in a twelve weeks' course, taken most largely by students who have but recently entered college."

Lest the somewhat massive proportions of the book should daunt the beginner, let us note, however, that of its 770 pages the half are occupied by the text-figures which illustrate every feature that is described. By their numbers and excellence these figures afford admirable aid to the letterpress.

Notwithstanding the size of the volume, Professor Salisbury's treatment of his subject is designedly simple and elementary. The new-fangled terms of the American school of physiography, which introduced, are clearly explained and illustrated, and there is no attempt to bring forward the whole battery of them. Thus, while 'consequent' and 'antecedent' streams are discussed, there is no mention of such further refinements as 'obsequents' and 'subsequents.' Every new science must require the introduction of new technicalities, and the word in which an idea first conveniently crystallizes out is likely to survive, even though it be no better than, say, 'peneplain.' Still, our innate conservatism forbids too hearty a welcome to the strangers, and it is perhaps pardonable in a British reader who chanced to light upon the picture of a butte (p. 171) to which is appended as an explanatory note "The butte is really a monadnock," that the phrase should bring with it a reminiscence of Lewis Carroll's quaint line "For the Snark was a Boojum, you see." But let that pass; 'butte' is good, and 'monadnock' also has its uses!

And now for a rapid glance at the contents of the work. It is divided into four parts of unequal length. Part i, the longest, of 180 pages, deals with the Lithosphere, in ten chapters, entitled: "Relief Features," "The Work of the Atmosphere," "The Work of Ground-water," "The Work of Running Water," "The Work of Snow and Ice," "Lakes and Shores," "Vulcanism," "Crustal Movements: Diastrophism," "Origin and History of Physiographic Features," and "Terrestrial Magnetism." Part ii, on Earth Relations, comprising only one chapter, of 24 pages, discusses the astronomical aspects of our globe. Part iii, on the Atmosphere, has 200 pages, divided into eight chapters, headed: "General Conception of the Atmosphere," "Constitution of the Atmosphere," "Temperature of the Air," "The Moisture of the Air," "Atmospheric Pressure," "General Circulation of the Atmosphere," "Weather Maps," and "Climate." This part is bountifully illustrated with meteorological maps of all kinds, both general and local, the local examples being here, as throughout the book, almost wholly American. Part iv treats of the Ocean, somewhat disproportionately as it seems to an islander—a prejudice of environment perhaps—in no more than 50 pages, divided into seven short chapters: "General Conceptions," "Composition of Sea-water," "The Temperature of the Sea," "The Movements of Sea-water," "The Life of the Sea" (brief and poor), "Materials of the Sea-bottom" (the same), and "Relation of the Sea to the Rest of the Earth" (only a little over a page of elementary generalizations by way of summary).

With a book of this kind it is of course impossible in our limited space to do more than this roughly to indicate its range. The outlook throughout is centred on the United States of North America, for whose students it was primarily written; but to the British reader it is stimulating from the freshness of its illustrations and examples, which bring vividly before him the magnificent diversity of conditions that obtains within the limits of the great republic.

A special feature of the book are the contour-maps which constitute the twenty-six plates, and are arranged to exemplify the various topographical forms described in the text and pictorially represented in the figures. These are intended to familiarize the beginner with the reading of such maps, and to lead him on to the systematic study of the larger official maps mentioned in lists given at the end of most of the chapters, where also the advanced student will find references to the technical literature of each subject. These map-plates are rendered pleasing in appearance by being printed in the three conventional colours, black, blue (water), and brown (contours). Among many advantages, this method of printing has some disadvantages, for one needs sharp eyes to read the contour-heights, so very sparsely bestowed on most of the maps; and there is also a too frequent recurrence of faulty registration, by which streams are displaced from their valleys, and contours are made to cross surfaces of standing water (e.g. pls. xviii and xx).

Some minor points that seem open to criticism (e.g. the too limiting definition of 'ravine' on p. 119; and the apparent hair-splitting in the sentence on p. 338—"The cones are often called volcanoes,

though they are really the results of volcanic activity") must pass without discussion. Of misprints we have noticed only two: one in the letterpress of fig. 701, where 'new moon' should read 'full moon'; and the other on p. 140, where, by the dropping of a letter, we get the strange-looking 'hills de gullies.' G. W. L.

II.—Problems of the Artesian Water Supply of Australia, with special reference to Professor Gregory's Theory; being the Clarke Memorial Lecture delivered before the Royal Society of New South Wales, October 31st, 1907; by E. F. Pittman, Government Geologist of New South Wales. Proc. Roy. Soc. N.S.W., vol. xli.

IN the September number of the Geological Magazine for 1907 there was a notice of Australian geology, and incidentally the subject of the Flowing Wells was dealt with, including a short account of Gregory's views thereon. In the following number of the Geological Magazine there appeared a letter from Dr. Malcolm Maclaren, in which he strongly protested against these views on the source of Australian artesian waters. Whilst concluding his letter, Dr. Maclaren indicated that some of his former colleagues in Australia would discuss the subject more fully.

This has now been done by one at least of the writer's colleagues in the Clarke Memorial Lecture to which attention is directed. After explaining the general principles of artesian flow, more especially according to American authorities, Mr. Pittman expresses his opinion that the view adopted by most American geologists has much to recommend it, viz., that all underground waters have their origin in rainfall. The material point, then, to be argued is, "Whether the artesian water supply of the Australian basin has been derived from rainfall, and has been stored in the porous sandstones under hydrostatic or hydraulic pressure, or whether, as contended by Professor Gregory, it has been evolved from underground masses of igneous rocks, and is forced above the surface in bores by the influence of temperature and rock-pressure."

Surely Mr. Pittman is here somewhat overstating his case, since it is doubtful if Professor Gregory maintains that the artesian supply of Australia is wholly due to the above-mentioned causes. He appears to admit the effect of ordinary artesian pressure in a number of instances, and indeed has entered into most elaborate calculations respecting the underground hydrostatic curve. The question between Gregory and Pittman really is, as to whether the alternative causes suggested by the former have any foundation in fact.

After his preliminary remarks the lecturer proceeds to consider the question under two heads: (1) the objections of Professor Gregory to the hydrostatic pressure theory, which are discussed and answered; (2) his suggestions as to the cause of the ascent of the water in the flowing wells.

(1) The objections. These are considered *seriatim*, and it will be sufficient to mention some of them, viz.: loss of head through friction;

rate of flow of underground waters; anomalies in temperature; anomalies in pressure; salinity of artesian waters and the presence of alkaline carbonates; zinc in Toowoomba water (?); tidal wells; outlet for artesian basin, etc., etc.

As regards the loss of head through friction, Mr. Pittman sees no such great difficulty, quoting well-known instances from the Dakota and Paris basins as disproving this notion of the loss of head through friction to anything like the extent claimed by Professor Gregory, whose own book, "The Dead Heart of Australia," may be quoted to show the incorrectness of these views.

The anomalies in temperature are no doubt very puzzling, as many of the flowing wells in Australia show the rate of increase to be 1° F. for every 22 feet, which is greatly in excess of the average of 1° F. for every 53 feet.

To explain this difficulty Mr. Pittman compiles a table showing an increase of 1° F. ranging from 130 feet to 17½ feet in depth, drawn from localities in Europe and America. Gregory rejects the explanation of "different ratios of conductivity" in the rocks themselves, and the lecturer admits that some of the high temperatures may be due to the bores having been put down to centres of expiring volcanic activity. "It is only reasonable to suppose that the porous Triassic sandstones which form the base of the artesian basin have also been intersected by many dolerite dykes which do not appear at the present surface." But are these anomalous temperatures any proof of the *plutonic* origin of the water? It is more or less an assumption, we believe, that there is any such thing as plutonic water. This is probably nothing more or less than Daubrée's *quarry-water*,[1] though possibly the Professor may consider the views of the eminent chemical geologist as somewhat out of date.

As regards anomalies in pressure, the consideration of this subject would lead us into a study of isopotentials, which can scarcely be followed without special topographical knowledge, but the subject of saline contents may occupy our attention for a moment. The following are the particulars of Gregory's objections under this head:—(1) that the water does not increase in salinity with sufficient regularity as it flows from east to west; (2) that the dissolved constituents vary irregularly in nature as well as in amount in the wells of the central basin; (3) that the presence of alkaline carbonates in the majority of the well-waters and of zinc in "the well of Toowoomba" are evidence in favour of the plutonic origin of the water. To the first two objections Pittman says there is nothing remarkable that in a distance of 600 miles there should be variation in the accidental constituents of the artesian water, as such variations occur in shallow wells in close proximity; moreover, he contends that the average salinity of the South Australian wells is distinctly higher than that of the wells in the eastern States. But the most extraordinary thing is the idea that the presence of alkaline carbonates should be quoted as evidence of plutonic origin. The artesian waters

[1] For an explanation of this term *vide* Review of Daubrée's "Experimental Geology," GEOL. MAG., 1879, p. 427.

of Iowa and Texas are shown to contain carbonates (chiefly of soda), and the artesian waters of the Cretaceous basin of Alabama also contain considerable quantities of alkaline carbonates. In any case it is unnecessary to go to any plutonic depths to discover the source of the alkaline carbonates in the Australian basin, and he points out the probable presence of felspars in the porous sandstones from which much of the water is derived. We might quote an instance much nearer home, viz. that of the artesian wells in the Chalk under London, where the soda salts (including carbonates) are said to increase with the depth of the bore. It appears that the presence of zinc in the well at Toowoomba was due to artificial contamination—not that the small amount discovered, even if the result of natural causes, could have been accepted as evidence of the plutonic origin of the water.

(2) The cause of the ascent of the water in the flowing wells. This, according to Professor Gregory, is due to the *internal heat of the earth* and *rock pressure*. The discussion on this latter subject raises some points of interest. He remarks that attention was first called to the importance of rock pressure in reference to flowing wells by Mr. Robert Hay. Mr. Pittman points out that it is an old theory, and was thought to have been disposed of by Arago early in the nineteenth century. But we may observe that there always has been a recrudescence of heterodoxy in all branches of human thought, so that it is not surprising to learn of others in Australia, like Mr. F. B. Gipps, advocating this view. On the whole, the weight of authority, especially in America, is against the rock-pressure theory, and an important official in that country, *apropos* of the Kansas flowing wells, writes to Mr. Pittman as follows:—"Rock pressure as a cause of artesian flows has been advocated by several geologists besides Mr. Robert Hay, but has never been supported by any real evidence, and has never received official sanction, nor has it been generally accepted by careful private investigators. In fact, it should be regarded simply as a suggestion advanced to explain flows for which no other cause was known at the time."

Both Mr. Pittman and Professor Gregory agree in deploring the waste of artesian waters throughout Australia. It seems probable that even under the hydrostatic theory those portions of the basin furthest from the intake must be, to a certain extent, dependent on previous accumulations. If this is the case the Australian borer, though not living entirely on his capital like the coal-miner, is using up resources which cannot immediately be replaced.

In a postscript Mr. Pittman points out that the rocks termed Triassic in this paper include the lower water-bearing sandstone (of fresh-water origin) of the great Australian artesian basin. In Queensland they are known as the Trias-Jura, and are there overlain in places by the Blythesdale Braystone, a porous marine sandstone, which forms the basal bed of the Lower Cretaceous system. This formation is not known to occur in New South Wales, where the artesian water occurs in the older Triassic (or Trias-Jura) sandstones.

W. H. H.

III.—Traité de Géologie. I: Les Phénomènes Géologiques. By Émile Haug, Professor of Geology at the Faculty of Sciences in the University of Paris. 8vo; pp. 546, with 71 photographic plates and 195 text-illustrations. Paris: Armand Colin, 1907.

THIS is a veritable picture-book of geology, with descriptions of phenomena and features relating to atmosphere, hydrosphere, lithosphere, pyrosphere, and barysphere. It embodies the latest results of observation and research, which are placed before the reader in a manner attractive as well as instructive, and withal characterized by terse and lucid explanation and sound judgment. We are, however, in this as in many other modern scientific books, brought face to face with an exuberance of technical terms, the use of which may be necessary as we specialize more and more, although their multiplication tends to vexation. Those who read steadily through this book may gather the meaning of terms as they progress, but to those who take it up for reference the absence of an index is a serious drawback that time will not wholly remedy. A volume such as this, even if it be the first part of a general treatise, requires an index. Moreover, the subject is likely to appeal to a number of readers and students who might not need the second or subsequent parts. A very useful feature of the work is the series of bibliographies appended to each chapter, in which from about ten to more than sixty references are included.

In a brief introduction the author explains the aims and objects of geological inquiry, and points out that Geodynamics, including Geomorphogeny, are the topics discussed in his present volume. Examples of geological phenomena are followed by explanations of Lithogenesis, Orogenesis, and Glyptogenesis, the formation of rocks, their upheaval, and sculpture; subjects dealt with in detail further on. The author then considers the general morphology of the earth, the distribution of life on land and in water, and especially the various conditions under which marine forms exist. Deutogenous or detrital sediments, as well as those of organic and chemical origin, are considered; and the subject leads on to that of Diagenesis, wherein the transformation of sediments, the effects of dissolution, decomposition, and recrystallization are dealt with. Concretions and dolomitization, peat, lignite, and coal are successively discussed.

The facies of formations is next explained as the sum of their lithological and palæontological characters in a certain area. Where the same facies prevails the formation is Isopic, where a different but still synchronous facies occurs it is Heteropic.

This subject, which is properly discussed from a natural history point of view, is a fascinating one for stratigraphical geologists, who have to deal not only with the occurrence of certain species forming palæontological zones or horizons irrespective of sedimentary conditions, but also with the occurrence of genera and species whose range is limited by depth of water and character of sea-bottom. The use of the term homotaxis is regarded as appropriate for strata with identical palæontological and lithological characters which occur at different chronological horizons in areas apart.

Various accumulations, such as oolite, bone-beds, and phosphates, are

dealt with. Under continental conditions there are deposits subaerial, alluvial, and laguno-lacustrine; so under marine conditions there are deposits neritic, bathyal, and abyssal. In the French language, as remarked by the author, there is no single word to express the adjective 'shallow': *peu profond* seems to be the usual term. He employs the word 'neritic' to indicate the truly littoral formations, remarking that the higher marginal deposits of ancient seas have nearly always been destroyed by subsequent erosion, so that the actual extent of strata preserved seldom corresponds to the limits of the ancient sea.

We turn now to the consideration of Geanticlinals and Geosynclinals: to areas of synclinal depression and deposition, and their relation to continental areas. The Pacific is described as a depression having a convex form, suggesting that it was an ancient continental site.

Metamorphism and the crystalline schists or crystallophyllian formations, plications and dislocations, fan-structure, erosion-thrusts, and torsion come in for due treatment. Here, as elsewhere, the examiner will find a mine of helpful terms. "What is meant by a Dissymmetric Brachyanticlinal?" would, for instance, be a capital question. The diagrams and views of folds and thrusts are very good, but some of the views might with advantage have been accompanied by explanatory diagrams in the text.

Volcanic phenomena and earthquakes are very fully treated both in text and illustration; and the views of the eruption of Vesuvius in 1906 and of the destruction caused by the Japanese earthquake of 1891 are striking and effective.

It is remarked that there is nothing to indicate with certainty that the volcanoes of Auvergne are extinct. Vesuvius in ancient times was not regarded as a volcano, until it awoke in A.D. 79. While generous acknowledgment is given to the work of others, we miss (on p. 260) a reference to the Report on the Eruptions of the Soufrière in St. Vincent, by Dr. Tempest Anderson and Dr. J. S. Flett (1902), although the "Volcanic Studies" of the former are noted in the bibliographic list.

Fumaroles, geysers, metalliferous veins, the origin of petroleum, and other subjects of practical interest are dealt with; including the depth to which water can penetrate in the rocky crust, the *nappe phréatique*, which may be interpreted as the plane of saturation or water-table, springs, and the action of subterranean water. Glyptogenesis, or the sculpturing of the earth's surface, is naturally attractive, whether in the form of corrasion or corrosion, chemical or mechanical water-action. There are good figures of honeycomb (alveolar or cellular) weathering, of decomposed basalts, of sand erosion, and of the remarkable wall of Tanaron in the Basse-Alpes, which recalls to mind the structural features of the ridge of tilestones near Llandeilo. The view of sand-dunes in the Sahara is excellent.

The action of running water (ablation), the meanders of rivers, the base-level of erosion, and other matters relating to potamology receive illustration and explanation. There are fine views of river gorges and also of glaciers, and the brief remarks on the excavation by glacial action of certain valleys and of fjords, afterwards occupied by sea, are treated with due indication of divergent opinions.

The final chapter deals with marine erosion, with beach lines, and the questions of oscillation of land and sea.

IV.—Bulletin of the Pennsylvania State College (June, 1907). Fasciculus of the School of Mines and Metallurgy. Small 8vo; pp. 155.

THERE are no less than seven Schools in this College, the subjects ranging from Languages to Engineering, but we only propose to notice the seventh, which is under the charge of Professor Wadsworth, M.A., Ph.D., who has been a Fellow of the Geological Society of London since the year 1889. His wide experience in the rich mining districts of Michigan pre-eminently fit him to take charge of a School of Mines.

The fasciculus consists largely of the details of the work which the students have to carry on from the first to the fourth year. There is a general notice of the scope and object of the school. "The instruction must comprise all things requisite to find and obtain the earth's mineral wealth and prepare it for the market. This requires that the students should be trained to prospect or to conduct exploitations in the forest and field; to distinguish the useful minerals and rocks; to understand the geological principles that govern the formation and association of useful mineral products, etc., etc." Thus it will be at once perceived that this school is animated by a thoroughly practical spirit, and there is no room for the amateur geologist here.

On p. 56 the work of the School of Mines and Metallurgy is arranged in groups in the following order:—

1. Geology.
2. Geological Laboratory.
3. Metallurgy.
4. Metallurgical Laboratory.
5. Mineralogy.
6. Mineralogical Laboratory.
7. Mining.
8. Mining Laboratory.
9. Mining Geology.
10. Mining Geological Laboratory.
11. Mining Law.
12. Ore Dressing and Coal Washing.
13. Ore Dressing Laboratory.
14. Palæontology.
15. Palæontological Laboratory.
16. Petrography.
17. Petrographical Laboratory.

In describing the methods adopted with reference to these courses a certain amount of repetition is inevitable. The subjects more directly relating to geological science include Geology, Mineralogy, Mining Geology, Palæontology, Petrography, and their respective 'laboratories.' Professor Wadsworth again points out how important it is for the student to endeavour "to understand the connection and structural relations that rock masses bear to one another, and to the valuable deposits that they contain." Amongst the textbooks used in this particular course (Geology) we are glad to notice some well-known British authors, such as the two Geikies, Bonney, Judd, and Milne. As regards structural geology more especially, we note the names of Green, Prestwich, Fisher, and other British authors. The 'Geological Laboratory' work includes a course of mapping, but it mainly resolves itself into a series of field-excursions, where the student can be taught at the 'bedside.'

A very brief allusion to the remainder of the five selected subjects must suffice. Mineralogy is intimately associated with Crystallography and Macroscopical Petrography. Under this heading Dana

Wadsworth, Story-Maskelyne, and Lewis are the leading textbook authorities. The 'Laboratory' plays a most important part in this section, where the practical work of examining, testing, and identifying specimens of minerals and rocks is carried on. "In this way each student is required to determine in his course from one thousand to three thousand different mineral specimens belonging to the selected species." In Mining Geology particular attention is given to the occurrence and use of stone, clay, lime, cement, coal, iron-ore, and other economic products worked in the State. The object of the courses in Palæontology "is to familiarize the student in the field and laboratory [? museum] with the more common fossils, particularly those that characterize the Palæozoic formations. The student will be practised in the determination of the varying types which he is expected to draw and describe." Petrography is considered under two heads, viz., Optical and Microscopical Mineralogy and Microscopical Petrography. In this course the alterations of minerals are especially studied. Amongst the textbooks quoted are Iddings, Van Hise, Hatch, and Harker.

Throughout this fasciculus Professor Wadsworth never fails to impress upon his readers how much benefit men engaged in prospecting have derived, or are likely to derive, from such studies, and more especially from Mineralogy and Mining Geology (p. 116). He seems to be conscious that four years is rather a short period for the absorption of such a mass of information as is afforded by the State College of Pennsylvania. We feel sure, however, that the finished article, after passing through all these courses and laboratories, ought indeed to be *factus ad unguem*.

V.—The Glaciation of East Lothian.

IN this country there are no geological papers more sumptuously printed and illustrated than those which in quarto form issue from the Royal Society of Edinburgh. One of these, just received by us, is entitled "The Glaciation of East Lothian, south of the Garleton Hills", Trans. R. Soc. Edin., vol. xlvi, by Professor P. F. Kendall & Mr. E. B. Bailey. In it the authors deal with the operations which took place during the retreat of the ice-sheet which invaded the region and overrode the Lammermuir Hills during the period of maximum glaciation. The general direction of the ice-movement was from W.S.W. to E.N.E., eventually turning east and a few degrees south of east, from the Garleton Hills towards St. Abbs Head.

The district is described as presenting "the special characteristics of an ice-dressed surface," the topography being that of a drumlin country. Long low mounds or ridges run parallel with one another, separated by shallow broad-bottomed grooves or valleys. Instead of being formed of Boulder-clay, as in the case of true drumlins, these mounds have been fashioned in solid rock and are merely coated over with Boulder-clay. Examples of 'crag and tail' are noted where ice met an isolated resistant mass of rock, and the excavation of a shallow

turn is pointed out where a change of slope occurred along one of the grooves. Attention is also called to the presence of large transported masses of Carboniferous Limestone, in one case one-third of a mile long and a quarter broad.

Turning to the phenomena attending the retreat with occasional re-advances of the ice-sheet, the authors remark, "Thus step by step the enveloping ice shrank back to leave the Lammermuirs standing like a stone in the midst of melting snows; and stage by stage the memorials of this retreat were furnished by the obstructed drainage of the hill country, joined by the waters issuing from the glacier itself."

The phenomena in question did not affect the higher portions of the Lammermuir Hills; they indicate the action of water impounded in front of the retreating ice-sheet, and serve to explain the anomalous drainage system, which could not have been produced under any existing circumstances. The peculiarities of the surface features were observed more than forty years ago by Professor John Young and Sir Archibald Geikie, and the latter suggested that they might be due to the modifying influence of direct glacial erosion. Thus instances were given of narrow glens or ravines, quite dry, and open at each extremity, along which, with the present configuration, no stream could ever have flowed. The present authors point out that many of the typical examples of these deserted ravines have been excavated entirely in drift deposits, and cannot therefore be vestiges of a pre-glacial drainage system. They are, in fact, overflow channels which have been cut by glacially diverted waters, and have failed in later times to retain streams.

There are, however, numerous glacial drainage-channels still occupied as watercourses, and to these special attention is drawn. They exhibit a marked tendency to the formation of 'corroms' and the consequent establishment of short cuts. The term corrom (cothrom), as remarked by the authors, is a Gaelic word used in place-names in the Ardgour district of Argyllshire to denote a delta-watershed. Its literal meaning is a 'balance,' and it is intended to illustrate that a stream issuing upon such a cone has the chance of flowing either the one way or the other. In the present district it has been found that there are many cases where a tributary stream has thrown out a cone or delta into a deserted glacial drainage-channel and established a watershed within it.

The authors deal with these highly interesting features, and describe the later erosion that has been produced by streams that have been left in occupancy of glacial drainage-channels. This erosion is seen in the winding gorges that have been carved on the floors of some of the ancient valleys.

It should be mentioned that the authors use the term corrom in reference to function and not to origin; remarking that "many a great beheaded valley must have found itself in just such plight and accepted a corrom as the watershed of its lower reaches."

The memoir, which is issued to the public at 4*s.* 6*d.*, is illustrated by four beautiful photographic plates, a colour-printed map, and six text-illustrations.

VI.—Geological Survey, Western Australia. Bulletin No. 27: Palæontological Contributions to the Geology of Western Australia. By Robert Etheridge, F. Chapman, and W. Howchin. 8vo; pp. 71. Perth, W.A.

THIS Bulletin contains five papers, all of them of considerable interest from the geological standpoint as well as from that of the palæontological. The first is a brief statement made by Mr. R. Etheridge on "Plant Remains from the Collie Coalfield," in which the writer, after citing the views as to the age of the beds entertained by Mr. H. P. Woodward (1891, 1894) and by Mr. Robert Etheridge, F.R.S. (1894), forms the opinion on the evidence of *Glossopteris* remains that the beds are of Permo-Carboniferous age, in this confirming his father's views, which, as will be shown in the sequel, were well founded. In the next paper, "Notes on Fossils from the Collie Coalfield, West Australia, in the Collection of the National Museum, Melbourne," Mr. F. Chapman refers to the conclusive settlement of the age of this coal-bearing stratum by Sir Frederick McCoy in 1898. The specimens upon which this important determination was based are described in detail and figured by Mr. Chapman from the new and valuable material secured for the Museum by Sir John Forrest. The species identified are *Glossopteris Browniana*, var. *Australasica*, Brongniart (sp. and var.); *G. Indica*, Schimper; *G. angustifolia*, Brongniart; *G. Gangamopteris*, Feistmantel; together with specimens of the rhizoma of *Glossopteris* (= *Vertebraria*), and some plant-fragments of uncertain affinities.

In addition to the plant-remains a small series of Foraminifera was obtained in the whitish sandstone accompanying the coal-seams. They proved from their exceptional minuteness very difficult to determine, but the presence among them of a characteristic Carboniferous species, *Valvulina plicata*, d'Orb., is an additional testimony, if such were required, to the correctness of the age assigned to the rocks from which they are derived. Their presence in strata associated with the Collie coal-beds is also interesting, as showing that these deposits are due to drifted material of marine or estuarine origin. The forms enumerated consist of the species above mentioned, together with *Truncatulina Haidingeri*, d'Orb., *Endothyra* sp., *Bulimina* sp., *Pulvinulina* cf. *exigua*, Brady.

The third paper is by Mr. R. Etheridge, and contains descriptions and figures of fossils from the Irwin River, W.A., collected by Mr. E. S. Simpson and Mr. C. F. V. Jackson. The fossils consist of casts and impressions, mostly badly preserved, and therefore difficult of determination. The following are the species: *Diclasma nobilis*, sp. nov., *Spirifera*, sp. ind., *Cyrtina carbonaria*, var. *Australasica*, Eth. fil., *Cleithyris Macleayana*, Eth. fil., *Productus subquadratus*, Morris, *Chaetes*, sp. ind., *Deltopecten subquinquelineatus*, McCoy, *Modiola* (?), sp. ind., *Myalina* (?) *Mingenewensis*, sp. nov.

The fourth paper is also contributed by Mr. R. Etheridge, and in this the Carboniferous fossils of the Irwin River are carefully described and figured. The facies of these fossils is stated to be that of the Carboniferous as distinguished from the higher Permo-Carboniferous.

One of the fossils, a Goniatite of the genus *Gastrioceras*, is of special interest, being of an unusual size. The following are the species identified: Foraminifera—*Nubeculavia Stephensi*, Howchin. Actinozoa—*Plearophyllum Australe*, Hinde. Polyzoa—*Fenestella tessula*, Lonsdale. Brachiopoda—*Diclasma* sp., *Seminula subtilita*, Hall (?), *Spirifera* sp., *Reticularia lineata*, Martin, *Productus semireticulatus*, Martin, *P. tenuistriatus*, var. *Foordi*, Eth. fil., *P. undatus*, Defrance, *P. subquadratus*, Morris (?), *Chonetes Pratti*, Davidson. Pelecypoda—*Aviculopecten Sprenti*, Johnston, *Aviculopecten* sp., *Conocardium* sp., *Stutchburia* sp. Gasteropoda—*Bellerophon costatus*, J. de C. Sowerby, var. Cephalopoda—*Gastrioceras Jacksoni*, sp. nov.

In the fifth and last paper Mr. W. Howchin describes a small collection of Foraminifera from a calcareous marlstone at Gingin, which are regarded by Mr. R. Etheridge as probably of Upper Tertiary age, though the evidence is insufficient to establish the exact horizon.

A. H. F.

VII.—Geological Survey, Western Australia. Bulletin No. 28: The Geology and Mineral Resources of Lawlers, Sir Samuel, and Darlot (East Murchison Goldfield), Mount Ida (North Coolgardie Goldfield), and a Portion of the Mount Margaret Goldfield. By Chas. G. Gibson, Assistant Geologist. 8vo: pp. 73, with 3 maps and 5 mining plans. Perth, W.A.

IN this report some of the most important of the mining centres of the State are dealt with. The area surveyed is described in the title above. As stated in previous reports, the rocks of the district consist of a complex of crystalline rocks, the age of which, as far as the evidence indicates, is Pre-Cambrian or Archæan. There is an acidic and a basic series, that is, there are 'granites' and 'greenstones,' the granites occupying the larger area, but not being the oldest rocks, as they are often intrusive in the greenstones. Both are traversed by numerous granitic and felspathic dykes, as well as by dolerite dykes traversing the granite of the Lawlers district. Quartz veins occur, apparently of later origin than the granite, generally at the junction of the latter with the basic rocks, indicating a possible genetic connection between the granite and some of the quartz veins.

Mr. Maitland, in his prefatory note, lays stress upon the fact that the quartz reefs are of later date than the granite intrusion, because this indicates that the reefs are not likely to be cut off, which might have happened had their formation preceded the intrusion. The question has obviously an important bearing upon the results of gold-mining in the area under review.

The report is well illustrated with photographic reproductions showing the physical features of the country, and with maps, plans, and sections of the mines in operation.

A. H. F.

VIII.—Catalogue of Students' Collection in Sedgwick Museum. By Henry Woods, M.A., F.G.S.

THE third edition has been issued (price *6d.*) of a "Catalogue of the Fossils in the Students' Stratigraphical Series," Sedgwick Museum, Cambridge, by Henry Woods, M.A. It will undoubtedly be welcome to many teachers as well as students, to those who write textbooks as well as to those who conduct classes, and we hope also to those who act as examiners. It will probably not be welcome to the majority of expert palæontologists or specialists. Nevertheless, as a *via media* it is an important sign of the times. Those who have to deal with students and amateurs who require only a general knowledge of geology and palæontology, know full well that to attempt to teach a knowledge of fossils combined with modern palæontological nomenclature is an almost hopeless task. Those who seek to become specialists in one or more branches of palæontology (for no one can be expert in all) must learn the older and more comprehensive names of fossils, as well as those applied to the present subdivisions both of genera and species. For them to neglect the history of the subject would be fatal. To the amateur, to the student who wishes to apply geological knowledge to engineering or mining questions, and to the more advanced geologist who cares not to grapple with the genealogical side of palæontology, a simpler system of nomenclature, such as that given in the present list, should be ample. Therefore, we rejoice to see in this Catalogue the familiar names of *Goniatites sphericus*, *Aviculopecten papyraceus*, *Avicula contorta*, *Waldheimia numismalis*, *Ammonites serpentinus*, *Rhynchonella spinosa*, *Ostrea gregaria*, *Cyprina Islandica*, and *Rhinoceros tichorhinus*.

REPORTS AND PROCEEDINGS.

I.—Geological Society of London.

Annual General Meeting.

February 21*st*, 1908.—Sir Archibald Geikie, K.C.B., D.C.L., Sc.D., Sec. R.S., President, in the Chair.

The Reports of the Council and of the Library and Museum Committee for the year 1907, proofs of which had been previously distributed to the Fellows, were read. It was stated that the flourishing condition of the Society had been marked, in the year under review, by a further increase in the number of Fellows, the number elected being 74—20 more than in 1906. Of these, 58 paid their admission fees before the end of the year, making, with 16 previously elected Fellows, a total accession of 74 in the course of 1907. During the same period, the losses by death, resignation, and removal amounted to 47—9 more than in 1906—the actual increase in the number of Fellows being, therefore, 27 (as compared with an increase of 12 in 1906). The total number of Fellows on December 31st, 1907, was 1278.

The balance-sheet for that year showed receipts to the amount of £3,109 17*s.* 10*d.* (excluding a balance of £216 1*s.* 7*d.* brought forward from 1906), and an expenditure of £3,148 2*s.*

Reference was made to the issue of the "History of the Geological Society", prepared and edited by Mr. H. B. Woodward. It was intimated that the Council had decided to publish, in a style uniform with that of the Quarterly Journal, a Centenary Record, which would include, besides a general account of the proceedings at the centenary celebration, the centennial address delivered by the President and the addresses of congratulation received from all parts of the world.

The list of Awards of the various Medals and Proceeds of Donation Funds in the gift of the Council was read.

The President handed the Wollaston Medal, awarded to Professor Paul von Groth, F.M.G.S., to Mr. F. W. Rudler, I.S.O., for transmission to the recipient, addressing him as follows:—

Mr. Rudler,—The Council of the Geological Society has this year assigned its highest distinction, the Wollaston Medal, to Professor Paul von Groth in recognition of the value of his lifelong services in the investigation of "the mineral structure of the Earth." His original researches have placed him among the leaders of mineralogy and crystallography in our day; and his right to that eminent position has been greatly enhanced by the genius which he has shown in the teaching of his subject, by the organization of his laboratory for advanced training, by the admirable arrangement and execution of his text-books, and by the zeal and success with which for thirty years he has edited and published his now indispensable "Zeitschrift für Krystallographie und Mineralogie." His laboratory has become the Mecca of modern mineralogy, to which pilgrims repair from all parts of the world to learn the methods of the great master at Munich. His remarkable personal charm has endeared him to all who have come into close contact with him, and who discover that he is at once one of the most retiring and yet most popular of scientific men.

It is to myself a peculiar pleasure that I should be privileged on the present occasion to transmit the award of the Council to so old a personal friend of my own. He will, I am sure, regard the Medal with special interest, since it bears the name and the effigy of one of the foremost of English mineralogists, whose reflecting goniometer was doubtless a familiar instrument in Professor von Groth's hands from his student-days onwards. In asking you to receive it for him, I would wish you to convey with it an expression of the cordial wishes of the Society for his prolonged health and activity. We earnestly trust that he will not only be able to complete the gigantic task of his "Chemische Krystallographie," but continue for many years thereafter to reap the fruits of his labour by witnessing the quickened advance of the science to which he has so unremittingly devoted his strenuous life.

Mr. Rudler, in reply, read the following message received from the recipient:—

Mr. President,—I regret that official duties at Munich prevent me from coming to London to receive the Wollaston Medal, and from thanking in person the Council of the Geological Society for the great honour conferred upon me.

As my researches in Physical and Chemical Crystallography have not been very closely related to Geology, while my Mineralo-geological work on the mineral deposits of the Alps, the rocks of the Vosges, etc., has been of itself too unimportant to have afforded a reason for the gift to me of the highest distinction that the Geological Society of London has to bestow, I am compelled to regard the award of the Medal as intended to be a recognition of my work, during many years, as a teacher of Mineralogy and Crystallography to pupils who were, many of them, Geological students.

I rejoice to be able to say that from no country have better pupils come to my laboratory and lectures than from England itself, and that it has been a great happiness to continue with such pupils the work which Professor Miller founded at Cambridge with his introduction of Rational Indices, and which my highly-esteemed friend Professor Maskelyne did so much to encourage at Oxford by his lectures on Crystalline Symmetry.

In this sense, as a fellow-worker in the scientific training of the junior mineralogists of England, I have pleasure in accepting, with the most hearty thanks, the distinction

conferred upon me, and hope to be permitted to give like help to other pupils from the same country in the more immediate future.

The President then presented the Murchison Medal to Professor Albert Charles Seward, F.R.S., addressing him in the following words:—

Professor Seward,—The Murchison Medal is awarded by the Council to you as a mark of appreciation of the services you have rendered to geological science by the skill, zeal, and success with which you have for many years pursued the study of fossil plants. Your researches have embraced a wide botanical range and an extended series of geological formations, while the materials on which you have worked have come to you from many different and distant regions of the globe. Your studies of the Wealden flora have enabled you to present an ampler and more vivid picture of the vegetation of later Mesozoic time than was before obtainable. Your discussions of the *Glossopteris*-flora and of the European and Eastern Mesozoic floras have been full of suggestion to geologists. It is only by trained and persistent students, who, like yourself, have an intimate knowledge of living forms, that the structure and genetic relations of the plants and animals of past time can be satisfactorily elucidated. We wish you many long years of active life, and we confidently expect that, from the Chair of Botany in Cambridge, you will continue to advance the study of Palæobotany, and will in this way sustain and extend the reputation of the great Cambridge geological school.

Professor Seward replied as follows:—

Mr. President,—I desire to express my sincere thanks to the Council of the Society for selecting me as the recipient of the Murchison Medal: the news of the award came to me as one of the pleasantest surprises that I have ever had. A student is not supposed to look forward to material rewards for what little he is able to contribute towards the advancement of Natural Knowledge; but, when a reward comes, it awakens feelings no less pleasurable than those of a schoolboy receiving his first prize. I little thought, sir, when I first became acquainted with your name nearly thirty years ago, that I should ever have the pleasure and privilege of receiving a Medal from your hands. As I have been for some years, officially at least, a botanist, the high compliment paid to me by the Society is the more appreciated. This is, perhaps, one of the very few occasions when it is pardonable to speak of oneself. The first stimulus I received which made me respond to the attraction of Geology, was supplied by some University Extension Lectures delivered by my oldest geological friend, Dr. Marr. A few years later I began to read Botany at the suggestion of Professor McKenny Hughes, a suggestion for which I have every reason to be grateful; but it was the fascination of geology which caused me to diverge from the path originally marked out for me, and to give my allegiance to Natural Science.

On looking through the list of Murchison Medallists I was reminded that last year the award was made to Mr. Harker; though I have often regretted that Palæontology did not secure his affection, I am proud to appear next him in so honourable a list. In my undergraduate days Harker was one of my best friends, whose generous help I am not likely to forget. I rejoice also to find myself in the company of Professor Goeppert and Professor Roemer in the list of Medallists. It was once my privilege to spend some weeks in examining the classic collections of Goeppert in the University of Breslau, where the hospitality of the late Ferdinand Roemer taught me that differences in age and nationality count for little among those whose lives are devoted to the common cause of Science. Professor Geinitz, another Murchison Medallist, received me in Dresden twenty years ago with a friendliness which made a lasting impression. The name of Professor Newberry reminds me of another friendly senior.

To follow such men as I have named is not merely an honour, but a strong incentive to do my utmost to render myself less unworthy of being permanently associated with them in the records of the Society.

In handing the Lyell Medal, awarded to Mr. Richard Dixon Oldham, to Mr. G. W. Lamplugh, F.R.S., for transmission to the recipient, the President addressed him as follows:—

Mr. Lamplugh.—In asking you to transmit to Mr. Oldham the Lyell Medal, which has been awarded to him, I would wish you to express to him the appreciation of the Council of the value of the work which he has done in the advancement of Geology. During his long connection with the Geological Survey of India, he was able to add much to our knowledge of the geological structure of that great dependency. At the same time he was always alive to the bearing of his observations on the wider problems of our science. Besides his ordinary official duties, he from time to time has undertaken special subjects of enquiry. Of these, probably the most important was his careful investigation of the effects of the great Indian Earthquake of June 12th, 1897. Since he retired from his Indian appointment he has continued to take part in the discussion of seismic phenomena, and he has written some noteworthy papers dealing more particularly with the relations of the subject to the internal constitution of the globe. I greatly regret his absence to-day from illness.

It would have been to me no small satisfaction that it should have fallen to me to present this Medal, for one of the pleasant memories of my life is that I counted his father among my friends. As the worthy son of a distinguished sire, he has carried on the family tradition. Will you tell him that the Society trusts that, as he is now once more resident in this country, we may often see him at our meetings, and that for many years to come we may be favoured with communications from him on the geological questions in which we are all interested.

Mr. Lamplugh, in reply, said:—

Mr. President, In the unavoidable absence of Mr. Oldham, I will ask your permission to read the following letter, explaining the circumstances, which I received from him this morning:

"If you are not, like me, laid up with a mild attack of the universal influenza, I should be very much obliged if you would represent me to-morrow, accept the Medal, and express on my behalf my gratitude for the favour which the Council has accorded me. The grant is the more gratifying as, since I have been free to follow my own inclinations, these have led me to a branch of our science which had almost ceased to be regarded as Geology, but finds its proper place in the 'Principles' of the founder of the Medal which I ask you to accept on my behalf."

In presenting the Balance of the Proceeds of the Wollaston Donation Fund to Mr. Herbert Henry Thomas, M.A., the President addressed him in the following words:—

Mr. Thomas,—The Balance of the Proceeds of the Wollaston Donation Fund has been by the Council awarded to you, in recognition of the value of your investigations into the composition of sedimentary rocks and also of the work done by you in the Palæozoic series of South Wales. The Society hopes that you may be encouraged to continue your interesting enquiries into the derivation of the finer sediment in ancient stratified formations—a subject which has hitherto been comparatively little studied, but from the pursuit of which much light may be expected to be thrown on the geographical conditions of former geological periods.

The President then presented the Balance of the Proceeds of the Murchison Geological Fund to Miss Ethel Gertrude Skeat, D.Sc., addressing her as follows:—

Miss Skeat,—The Council has this year awarded to you the Balance of the Proceeds of the Murchison Geological Fund as a mark of appreciation of your geological work, especially among the Glacial deposits of Denmark and the Lower Palæozoic rocks of Wales. It is with much gratification that we hail in you another woman who is worthily placed on the roll of those who have gained our awards. We trust that you may be able to devote many active and happy years to the further prosecution of the studies in which you have shown such conspicuous success.

In presenting a moiety of the Balance of the Proceeds of the Lyell Geological Fund to Mr. Harold J. Osborne White, F.G.S., the President addressed him in the following words:—

Mr. Osborne White,—A moiety of the Balance of the Proceeds of the Lyell Geological Fund has been awarded to you by the Council, in acknowledgment of the service which you have rendered to Geology by your researches among the Cretaceous

and Pleistocene deposits of Berkshire and Oxfordshire. Your detailed investigation of the zones of the Upper Chalk has brought to light some interesting inflections of flexures and of a considerable erosion of the Chalk before the deposition of the Reading Beds; while your papers on the Plateau- and Valley-Gravels in the western part of the London Basin have important bearings on the history of the rivers in that region and on the origin of the present configuration of the ground. We hope that you may be encouraged to continue and extend these observations.

The President then handed the other moiety of the Balance of the Proceeds of the Lyell Geological Fund, awarded to Mr. Thomas Franklin Sibly, B.Sc., to Professor E. J. Garwood, M.A., for transmission to the recipient, addressing him as follows:—

Professor Garwood,—A second moiety of the Balance of the Proceeds of the Lyell Geological Fund has been assigned to Mr. Sibly, on whose behalf I would ask you to receive it, as a mark of the Council's appreciation of the zeal and ability with which he has applied the method of zonal classification to the Carboniferous Limestone of various districts in England. There still remain many tracts of the British Isles in which that portion of the Palæozoic series has never yet been worked out in detail. We shall be glad if he will be encouraged to enter some of them, and thus to continue the work which he has already so successfully pursued.

The President then proceeded to read his Anniversary Address, giving first of all Obituary Notices of several Fellows deceased since the last Annual Meeting, including Prof. Marcel Bertrand (elected For. Memb. in 1899); Dr. E. Mojsisovics von Mojsvár (elected For. Memb. in 1893); Prof. Carl Klein (elected For. Corresp. in 1903); Sir Richard Strachey (elected a Fellow in 1851); Sir James Hector (el. 1861); C. L. Griesbach (el. 1874); the Rev. R. Baron (el. 1889); Prof. B. J. Harrington (el. 1883); Dr. E. J. Routh (el. 1864); Mark Stirrup (el. 1876); Lord Allendale (el. 1851); A. B. Wynne (el. 1860); J. F. Walker (el. 1867); Robert Law (el. 1886); Edward Power (el. 1892); P. L. Addison (el. 1888); and T. W. H. Hughes (el. 1865).

He then dealt with the published work of the Geological Society of London during the first century of the Society's existence, describing in the first place the traces of the Neptunist and Vulcanist controversy, as preserved in the early papers published by the Society. The contributions to Geology which had appeared in the "Transactions," "Proceedings," and "Quarterly Journal," were discussed under five heads: (1) British Geology; (2) Foreign Geology; (3) Petrography; (4) Palæontology; and (5) Physiography. In each of these divisions a rapid review was offered of the general character of the contributions presented to the Society, with a more particular reference to some of the outstanding papers, especially to those which inaugurated a new departure in geological research. In the last portion of the Address reference was made to certain contrasts which such a review as had been given presented between the past and the present character of the papers published by the Society. Some of the conclusions to be drawn from the contrast were urged on the attention of the Fellows. The heritage of distinction which had been handed down from the founders of the Society and their successors was a precious possession of which every Fellow might well be proud, and which ought to be continually borne in mind as a stimulus to sustain and extend the Society's prestige.

The Council elected for the ensuing year is as follows:—
Officers: President: Professor W. J. Sollas, Sc.D., LL.D., F.R.S. *Vice-Presidents:* Frederick W. Rudler, I.S.O.; Aubrey Strahan, Sc.D., F.R.S.; J. J. H. Teall, M.A., D.Sc., F.R.S.; and A. Smith Woodward, LL.D., F.R.S. *Secretaries:* Professor E. J. Garwood, M.A.; and Professor W. W. Watts, M.A., M.Sc., F.R.S. *Foreign Secretary:* Sir Archibald Geikie, K.C.B., D.C.L., Sc.D., LL.D., Sec.R.S. *Treasurer:* Horace W. Monckton, Treas.L.S.
Ordinary Members of Council: Professor S. H. Cox, F.C.S.; Alfred Harker, M.A., F.R.S.; W. H. Hudleston, M.A., F.R.S.; F. L. Kitchin, M.A., Ph.D.; George W. Lamplugh, F.R.S.; Richard Lydekker, B.A., F.R.S.; Professor Henry A. Miers, M.A., F.R.S.; Richard Dixon Oldham; Professor Sidney Hugh Reynolds, M.A.; Leonard J. Spencer, M.A.; Charles Fox Strangways; Richard H. Tiddeman, M.A.; Henry Woods, M.A.; and George William Young.

II.—Palæontographical Society.—The sixty-first annual meeting of the Palæontographical Society was held on March 20th, in the Geological Society's rooms, Burlington House, W., Dr. Henry Woodward, F.R.S., President, in the chair. The annual report alluded to the unusually varied contents of the volume for 1907. It provides indexes and title-pages for several monographs completed or discontinued. The Council favoured the plan of publishing smaller works; the current volume included a complete Monograph of British Conularia, by Miss Ida L. Slater, with five plates drawn by the authoress. Losses in membership by death had scarcely been repaired during recent years, and the Council welcomed a contribution from the Carnegie Trust for the Universities of Scotland, which provided five plates of Scottish Carboniferous Fishes, described by Dr. Traquair. Mrs. G. B. Longstaff, Mr. H. A. Allen, Dr. F. A. Bather, and Mr. William Hill were elected new members of Council, and Dr. Henry Woodward, F.R.S., President, Dr. G. J. Hinde, F.R.S., Treasurer, and Dr. A. Smith Woodward, F.R.S., Secretary.

III.—Zoological Society of London.—*April 7th*, 1908. Dr. Henry Woodward, F.R.S., Vice-President, in the Chair.

On behalf of Mr. Thomas Codrington, Dr. A. Smith Woodward, F.R.S., F.Z.S., exhibited a collection of 168 stones, weighing altogether 7 lbs. 13 oz., taken from the stomach of an elephant shot by Mr. H. Thornicroft in Northern Rhodesia. The animal was a large male, with tusks weighing 45 lbs. each. The stones showed no signs of attrition.[1]

Dr. C. W. Andrews, F.R.S., F.Z.S., exhibited a restored model of the skull and mandible of *Prozeuglodon atrox*, And.[2] This animal is one of the links uniting the true Zeuglodonts with the land Creodonts. It is found in the Middle Eocene of Egypt, where also the earlier type, *Protocetus*, was discovered by Fraas at a somewhat lower horizon. The model was constructed by Mr. F. O. Barlow for the British Museum of Natural History.

[1] The habit of swallowing stones to assist the gizzard in digestion is common to birds; crocodiles also are found to follow the same practice. Stones have likewise been found within the ribs of several fossil marine reptiles. Although stones have more than once been found in the stomachs of elephants, these mammals do not require such artificial aids to digestion; it therefore seems to imply a depraved taste on the part of the individual and not a normal healthy practice.

[2] See *ante*, pp. 209–212 and Plate IX.